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THE MERRIMACK: DESIGNS FOR A CLEAN RIVER. ALTERNATIVES FOR MANA--ETC(U)
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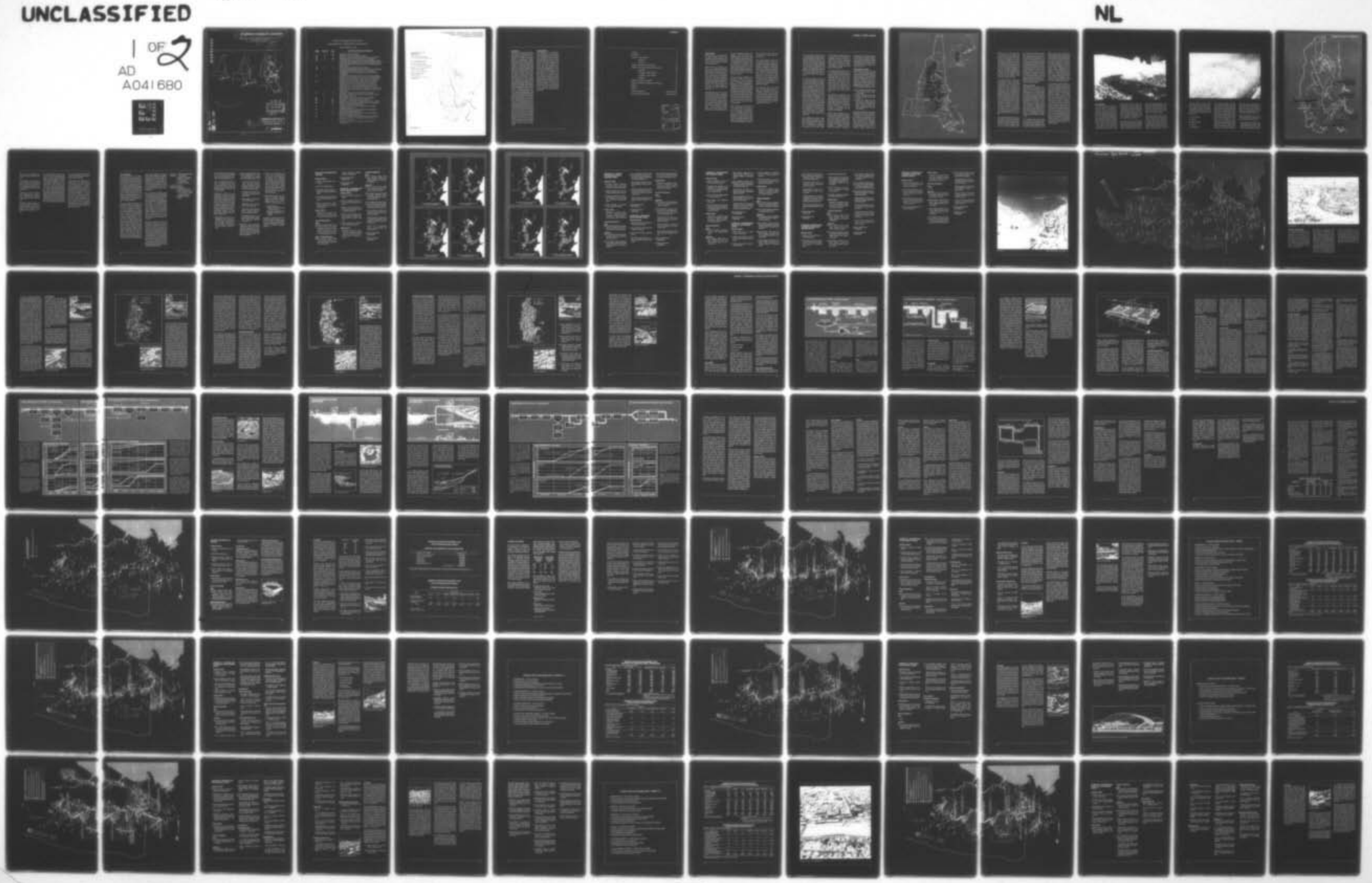

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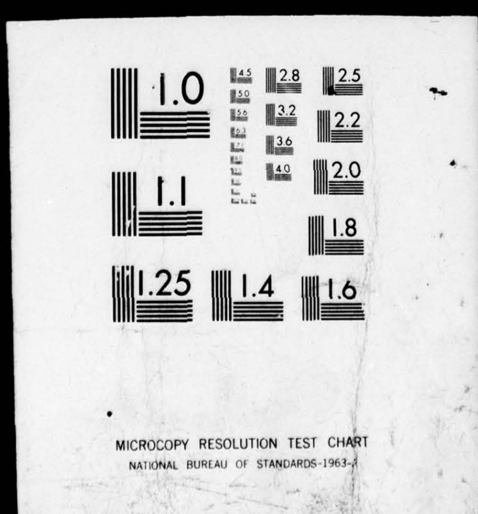

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THE MERRIMACK: DESIGNS FOR A CLEAN RIVER

Alternatives for Managing Wastewater in the Merrimack River Basin.

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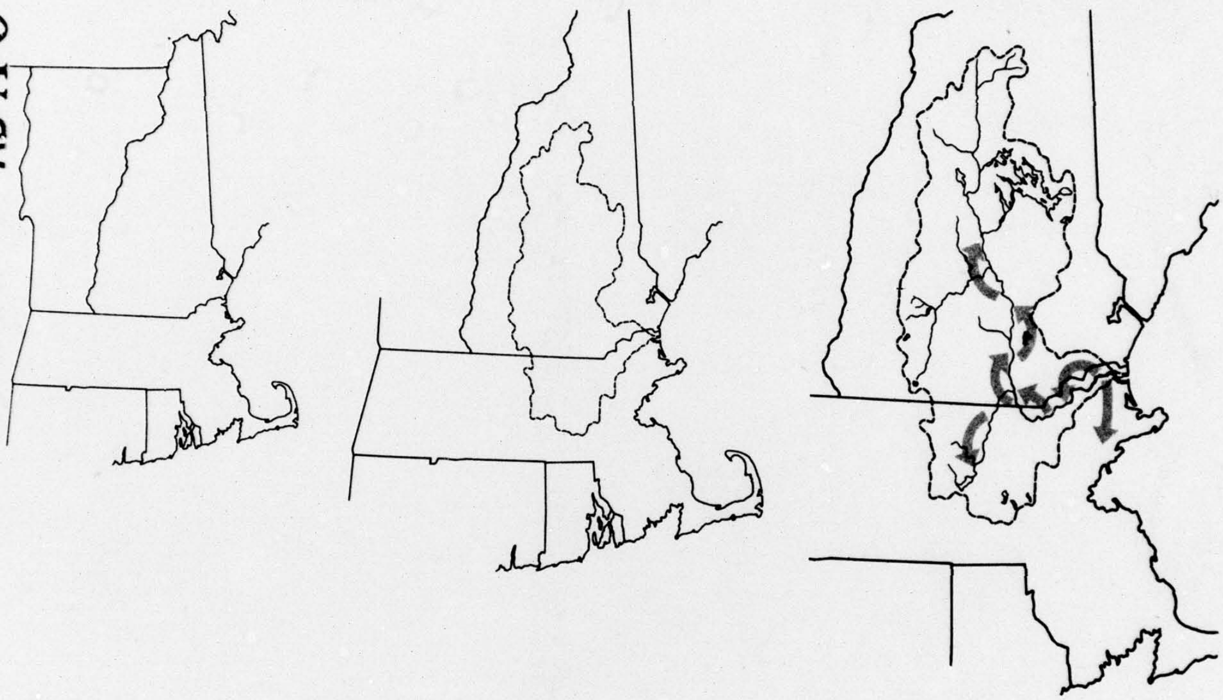

9 Summary rept.

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Errata Sheet to Summary Report Titled --

THE MERRIMACK: DESIGNS FOR A CLEAN RIVER

dated September, 1971

Page	Column	Line	Corrections/Deletions/Additions
5	3	22	Substitute "and" for "the"
13	2	19	The word "Part" should read "part".
18	1	1	The word "Decentralized" should read "Centralized".
29	2	28	Substitute the word "Domestic" for Domestice".
30	-	-	In the flow chart, the words "Primary Effluent" should read "Secondary Effluent" and "Primary Effluent" should be placed under the horizontal arrow from the Sedimentation Tank.
30	2	8	Add a comma after the word "oxygen".
36	-	-	In O_2 Demanding Chart for Basic Wastewater Treatment substitute the word "Biochemical" for the word "Biological", the word "Biochemical" should read "Chemical".
36	-	-	In Advanced Wastewater Treatment for O_2 Demanding Chart, the word "Biochemical" should read "Chemical"; and the word "Biological" should read "Biochemical".
40	-	-	In the O_2 Demanding Chart under Basic Wastewater Treatment, the word "Biochemical" should read "Chemical" and the word "Biological" should read "Biochemical". In the O_2 Demanding Chart under Advanced Treatment, the word "Biological" should read "Biochemical" and the word "Biochemical" should read "Chemical".
78	6	8	In table of Estimated Cost Breakdown (Capital Expenditures) the amount "829.4" in the total column should read "329.4".
82	3	4	The quantity of "7MGD" should read "17MGD".
86	-	21	The figure "54MG" should read "54MGD".
89	1	14	Delete the word "floor" and substitute the word "flood".
90	3	16	After the word regional insert a symbol for Regional Tertiary Treatment Facility (T).
93	-	2	"(MGD irrigation season)" should read "(19 MGD irrigation season)".
93	-	6	Delete "(22MGD irrigation season)" and substitute "(19 MGD irrigation season)".
93	-	10	Delete "(40 MGD irrigation season)" and substitute "(36 MGD irrigation season)".
94	-	-	In line 1 of Estimated Annual Operating Cost table the amounts of "$7.3" for Nashua and "$5.7" for F-L should be reversed.
97	1	1	Delete the word "Decentralized" and substitute "Centralized".

THE MERRIMACK: DESIGNS FOR A CLEAN RIVER
ALTERNATIVES FOR MANAGING WASTEWATER IN THE MERRIMACK RIVER BASIN

A FEASIBILITY STUDY PREPARED BY

NORTH ATLANTIC DIVISION
U.S. ARMY CORPS OF ENGINEERS

IN COOPERATION WITH

NEW ENGLAND DIVISION
U.S. ARMY CORPS OF ENGINEERS

REGION 1 OF THE ENVIRONMENTAL PROTECTION AGENCY

STATE OF NEW HAMPSHIRE

COMMONWEALTH OF MASSACHUSETTS

NEW ENGLAND RIVER BASINS COMMISSION

SEPTEMBER 1971

AUTHORITY

The Merrimack Wastewater Study is being carried out under the authority of Public Law 89-298, Rivers and Harbors Act of 1965, which established the Northeastern United States Water Supply Study (NEWS). Mandated to assure adequate water supplies for the great metropolitan centers of the Northeast, the United States Army Corps of Engineers has begun to investigate comprehensive wastewater management to make now polluted waters available for the public's growing water needs. Recognizing that pollution control has direct bearing on the welfare and prosperity of the Nation's most populous region, the Office of Management and Budget and the Appropriations Committees of both Houses of the Congress approved the reallocation of N.E.W.S. funds in April, 1971, to a pilot wastewater study of the Merrimack River Basin. This is one of five such feasibility studies authorized, the others examining the wastewater problems of San Francisco, Chicago, Detroit, and Cleveland. All five have been carried out by the Corps of Engineers within a cooperative agreement between the Department of the Army and the Environmental Protection Agency. The work which this volume documents has been performed by a special Task Force made up of Corps personnel, staff from several Federal agencies, including the U.S. Geological Survey, and the Soil Conservation Service, and consultants, all under the direction of the North Atlantic Division, Corps of Engineers.

COORDINATION

The development of complementary alternative schemes for wastewater management was made within an extremely short time frame. The EPA, States and local interests were brought into the scheme formulation process through workshops and monitor sessions in which they were afforded opportunities to offer suggestions, to object where necessary, with a view, above all else, to contribute to the proceedings. It is realized, however, that review within the time frame available placed an intolerable burden on the manpower and resources of the State agencies and therefore some of them were not able to participate in the review of the final draft. However, the formal review will afford the opportunity for full review and comment by all concerned.

CONTENTS

DECLARATION

We are a nation rich in resources. Our fathers found in this land the supplies of coal and metals, oil and timber that made the United States and its economic growth a wonder of the modern world.

Given the gift of hindsight, however, we can legitimately question the wisdom of the way in which that preeminence was achieved and the cost, social as well as economic, that it exacted from the American landscape. Too often, the development of our natural resources has amounted to senseless exploitation; too often there was no harvest, only butchery. The virgin forest is all but gone. Our cities strangle on fouled air and blue rivers are only a memory.

The shabbiness of our environment and the great danger to the quality of American life that it represents has only recently caught the attention of the public. In the area of water pollution, for example, effective control technology has been available since the end of World War I. For the most part, though, even in our major rivers like the Merrimack, it has gone unused and the filth of domestic sewage and industrial waste has grown progressively worse. Why was nothing done? Perhaps it was apathy, public and private, which let us tolerate the degradation of the water. Maybe industry was unwilling to part with a share of its profits. Or perhaps the river itself, with its size and strength, suggested a false confidence in Nature's cleansing power. Whatever the reason, the record stands: Pollution!

Today, that history of neglect is beginning to change. With the implementation of known technologies, it is possible to upgrade the Merrimack. The Commonwealth of Massachusetts and the State of New Hampshire have initiated forceful programs to construct the treatment plants needed to handle the 120 million gallons of sewage discharged raw into the Merrimack every day. More and more, industries are coming to recognize their obligation to a decent environment and beginning to treat or recycle their own process waters.

These measures will improve the river substantially. But they are only the first phase of the total effort. The pollution problem grows ever more complex and new technologies must be employed to supplement the time-tried ones. Great efforts have already gone into planning for upgrading the River. Now even greater energies are required to fully reclaim it and to restore it in the mind of the public as an object of pride.

This report presents to those who are concerned about the future of the Merrimack Valley a range of alternative wastewater management systems. Compatible with existing State plans, these seven strategies aim at achieving maximum feasible water purity in the wastewater produced by the major urban areas along one of the Nation's dirtiest waterways. The solutions suggested are flexible; their technical components are interchangeable and represent only tools with which to attain the same goal.

But they offer more than clean water. They promise new social and economic opportunities for an entire region; improving deteriorated urban waterfronts; increasing agricultural yields; guiding the growth of industry and population; and promoting a deep aesthetic response in the people who have been without their river too long.

It is a paradox of our time that the more urbanized and impersonal our society becomes so much more dependent Americans become on one another. On the face of things, the city dweller is a rugged individual who can ignore the rest of humanity and go about his business as he pleases. The essentials for his daily activities are within easy reach — food in the supermarket, power under the street, water in the tap and so on.

On closer examination, however, he is not the self-sufficient consumer of goods and services he appears: he is a creature living inside a delicate life support system. Though people seldom stop to consider it, without the delivery systems which bring urban populations the essentials basic to life, survival for such large groups of people so close together would be impossible. In fact, urban life goes on almost in defiance of the natural order of things. The physical environment is remote and, by the peoples remoteness from the sources of production, they are vulnerable to the effects of supply system failure. We already know the consequences of a regional power failure. What would happen, if there was no more water in the urban tap?

The Northeastern United States Water Supply undertaken by the Army Corps of Engineers has shown that the possibility is a very real one. In metropolitan southeastern New England alone, water needs are expanding so rapidly that present supplies will soon become inadequate. Unless new sources of clean water are found — and found quickly — the extraordinary restrictions placed on water use during the drought of the early Sixties will become commonplace.

The obvious place to look for water is in rivers like the Merrimack. In fact, a meeting of Federal and State resource planners in May, 1970, concluded that the River was a likely source for large quantities of fresh water. There is one serious snag in that plan, though, a constraint on using the Merrimack for water supply is as obvious as the river's smell. It is a sewer. Before we can use it, we must first make it clean.

The clean-up is underway. The States of New Hampshire and Massachusetts and the Environmental Protection Agency are proposing to apply basic secondary treatment to wastewaters throughout the Basin. When completed, a considerable measure of cleanliness will be achieved. The question is, will the water be clean enough?

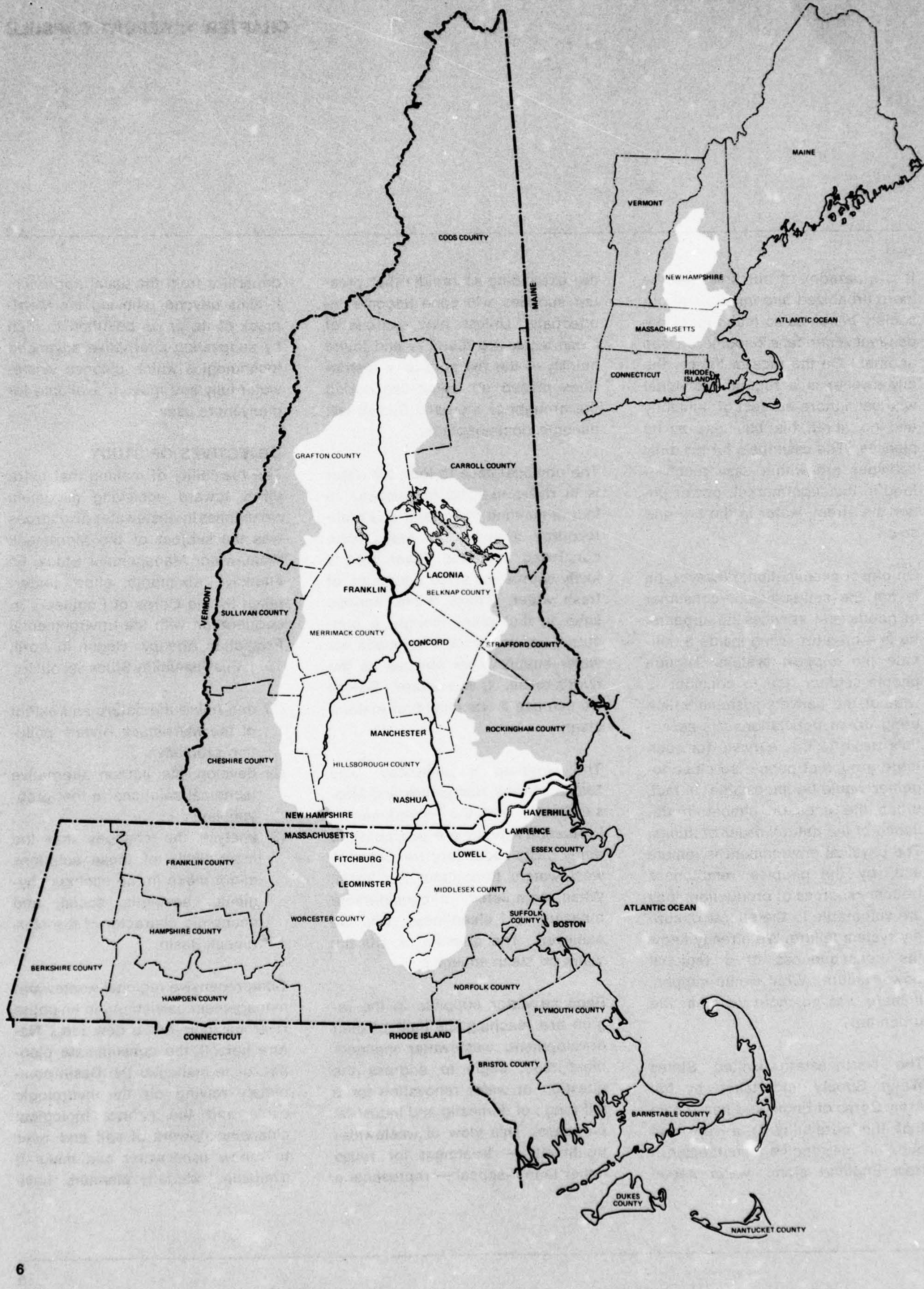
Because water supplies in the region are reaching the limit of their development, wastewater management must begin to address the question of water renovation for a full range of domestic and industrial purposes. This view of wastewater treatment — treatment for reuse rather than disposal — represents a departure from the usual approach. It aims beyond relieving the Merrimack of its gross pollution burden by suggesting alternative advanced technologies which cleanse wastewater fully and make it available for many more uses.

OBJECTIVES OF STUDY

The feasibility of making that extra effort toward achieving maximum cleanliness in wastewater discharges was the subject of the Merrimack Wastewater Management Study, an intensive six-month effort undertaken by the Corps of Engineers in cooperation with the Environmental Protection Agency. Begun in April, 1971, this Feasibility Study set out to:

(1) determine the nature and extent of the Merrimack River's pollution problem
(2) develop the screen alternative technical solutions to that problem; and
(3) analyze the changes that the most likely of those solutions might make in the ecologic, hygienic, aesthetic, social, and economic character of the Merrimack Basin.

Comprehensive regional wastewater management carried out in an entire river basin is not a new idea. Nature herself, the consummate planner, once managed the Basin completely relying on the hydrologic cycle and the natural biological cleansing powers of soil and river to renew used water and make it available. Modern planners have


MAINE
VERMONT
NEW HAMPSHIRE
MASSACHUSETTS
CONNECTICUT
RHODE ISLAND
ATLANTIC OCEAN
COOS COUNTY
MAINE
GRAFTON COUNTY
CARROLL COUNTY
LACONIA
FRANKLIN
BELKNAP COUNTY
VERMONT
SULLIVAN COUNTY
MERRIMACK COUNTY
CONCORD
STRAFFORD COUNTY
MANCHESTER
ROCKINGHAM COUNTY
CHESHIRE COUNTY
HILLSBOROUGH COUNTY
NASHUA
NEW HAMPSHIRE
MASSACHUSETTS
HAVERHILL
LAWRENCE
FRANKLIN COUNTY
FITCHBURG
LOWELL
ESSEX COUNTY
LEOMINSTER
MIDDLESEX COUNTY
ATLANTIC OCEAN
WORCESTER COUNTY
SUFFOLK COUNTY
BOSTON
HAMPSHIRE COUNTY
BERKSHIRE COUNTY
HAMPDEN COUNTY
NORFOLK COUNTY
PLYMOUTH COUNTY
CONNECTICUT
RHODE ISLAND
BRISTOL COUNTY
BARNSTABLE COUNTY
DUKES COUNTY
NANTUCKET COUNTY

pointed out for many years that the fragmentation of jurisdictional control and the insular attitude of most river communities were liable to destroy the utility of the river as anything but a transporter of wastes. For whatever reasons, their counsel went unheeded. The degradation of the river has become complete, and now only man-made strategies applied in an all-out campaign can reclaim it. Nothing less than a sense of mission in the people it could serve so well can restore it. That is what this report is all about.

The Merrimack River is an excellent choice for a study of this kind. Its proximity to many urban areas in desperate need of water has already been noted. It has been the subject of several antecedent research efforts which have amassed considerable data. Moreover, aggressive programs to construct basic treatment plants have been undertaken by the states of New Hampshire and Massachusetts; the expertise of their water pollution control agencies is invaluable. And finally, the pollution problem in the Merrimack is an obvious one. Pollution is a clear fact of life to the residents of the Basin and an impediment to the healthy development of the region's economic and social potential.

Given these foundations, the principal objective set for the Task Force, assembled to perform the Feasibility Study, was the ultimate achievement of maximum feasible water purity — no small undertaking in a river whose current condition classifies it as unfit for human contact. *The philosophy which guided their thinking was that wastewater is a resource too valuable to discard and that its fullest and best purpose would be to make it and its constituent pollutants available for re-use.* Further, the study team realized that it was looking at more than an engineering problem. A clean river promised a new prosperity suited to the people of the Basin. It offered an environment renewed and made not only liveable but delightful. Together, the Task Force set about determining whether that kind of Merrimack was even possible.

SCOPE OF STUDY

The Merrimack Wastewater Management Study focused on the congested urban and industrial areas responsible for the heaviest pollution loads and most in need of future water supplies. These sub-regions included the developing area along the Winnipesaukee River, Concord, Manchester, and Nashua, in New Hampshire, and the cities of Fitchburg, Leominster, Lowell, Lawrence, and Haverhill in Massachusetts. Areas outside the boundaries of the Basin were included only to the extent that their water needs or capabilities for wastewater renovation affected water planning in the Merrimack.

The Feasibility Study documented by this report, its ancillary Technical Appendices and Annexes examined existing data assembled from previous studies prepared under Federal, state, local, and private auspices. Because its purpose was a penetrating, action-oriented assay of the pollution control possibilities in an entire river system, new data collection was held to a minimum. Its findings, therefore rely heavily on the best professional opinions of expert staff — Federal and state agency people, independent consultants, and academicians who brought a range of disciplines to bear on the Merrimack problem. The physical sciences, biology and social science, architecture, demography, and engineering to name a few have all been represented.

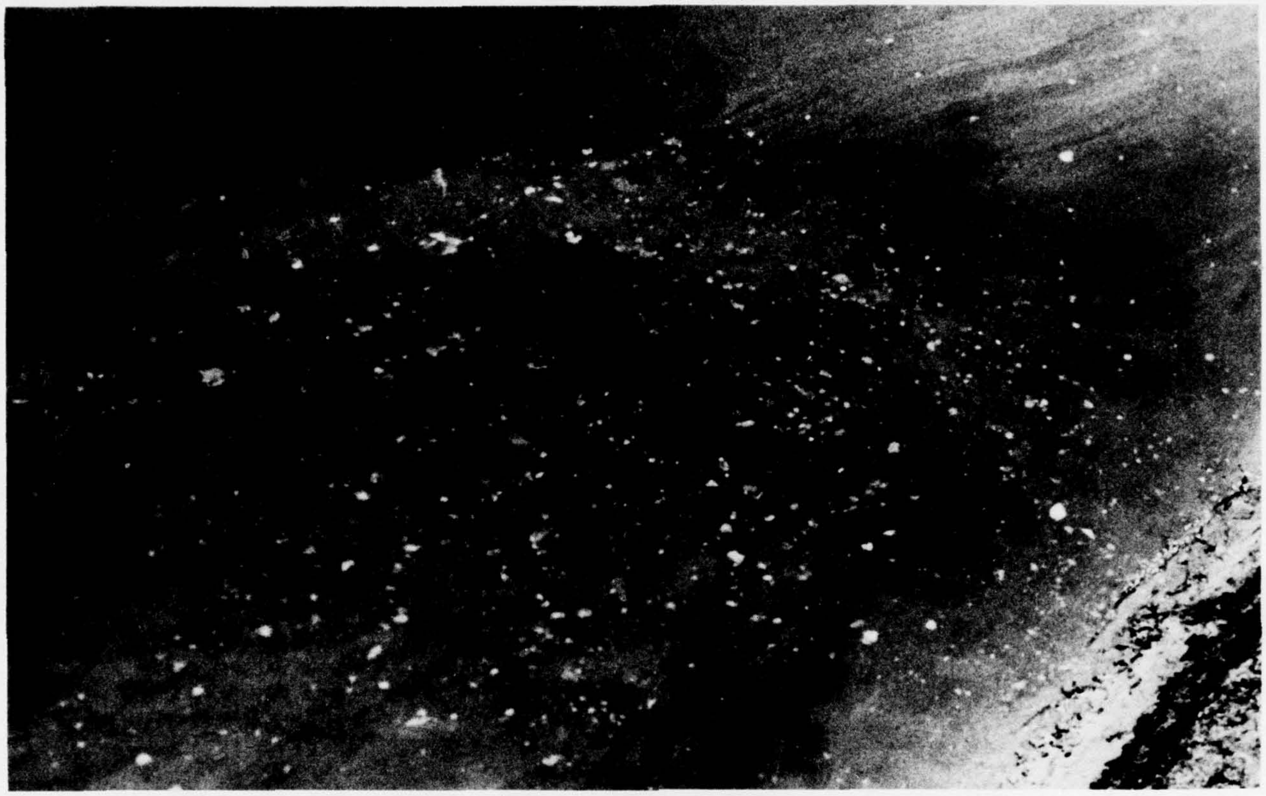
Their collective product is seven alternative schemes through which the major wastewater discharges into the Merrimack River can be thoroughly cleaned. Described in Chapter 4, along with the current EPA-state program for the Basin, they are options, *not dicta*. The Task Force recognized from the outset that its work in this phase of the project was only a beginning. *The ultimate decision on which scheme or which components of several schemes might best serve the whole of the Basin remains to be seen.* But the public must decide what is to become of the river, and soon. It is the purpose of this report to give all the decision-makers the facts. If it does no more than to make the options for comprehensive regional recovery clear or the decision to reject them explicit, it has succeeded.

THE PROBLEM

A dying river has many problems. Some are related to the quality of the water itself. It is possible, for example, to determine what substances are present in a given water sample, develop appropriate measures, and express contamination readings numerically. But other pollution problems are not so straight forward. These involve the communities — plant, animal, and human — which depend on the river as part of their environment. Conditioned by the healthiness of the stream, their relationships with the water and among each other are inextricably complex and not always amenable to quantification. Thus, to characterize the pollution problem in the Merrimack, we must look both at individual constituent pollutants and the aggregate subjective effects they produce in the ecosystem.

By source, there are three broad classes of pollution which degrade water quality in the Merrimack River Basin; domestic sewage, industrial waste, and stormwater. All are produced in greatest quantities in urban areas with dense population concentrations, large industrial complexes, and substantial acreages of paved land which promote rainwater and snowmelt runoff.

Generally, domestic sewage is water that has been used in the home for laundry, bathing, food preparation or to carry away human wastes. It is heavily organic and can contain sophisticated pollutants like those found in special household cleaning agents. Industrial wastes, though



generally smaller in volume, can contain more intensive pollutants; toxic cyanides, lime, heavy metals, and synthetic organics. Five types of industry account for the bulk of process water discharged into the Merrimack:

(1) pulp and paper

(2) textiles

(3) leather tanning

(4) plastics

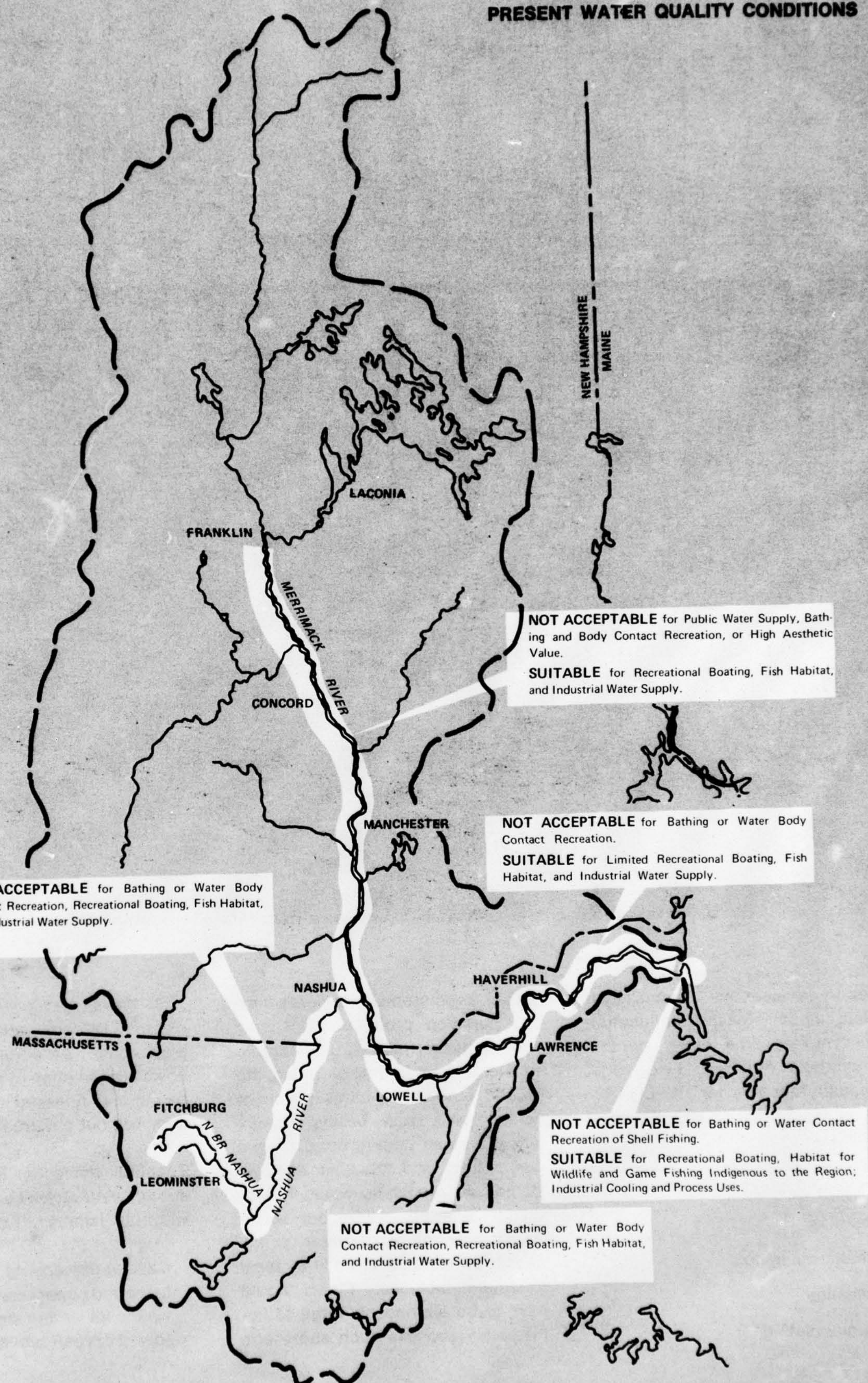
(5) metal plating

Finally, even stormwater poses serious pollution problems. Not only does rainwater pick up undesirable substances as it washes along the ground, but in many cities it is channeled from catch basins directly into the same underground sewers that collect and transmit sewage. Mixed with domestic waste it produces a more dilute but much larger flow of wastewater which cannot be handled directly by most treatment facilities. Plants would have to be enormously large to immediately process such short-term high flows, and overdesigning for capacity seldom occurs because of high costs. As a result combined flows are too often bypassed around plants and released directly into a river without any treatment at all.

Together domestic, industrial, and storm wastewaters burden the River with four families of pollutants:

Oxygen-demanding wastes like feces and paper processing wastes which lower the amount of dissolved oxygen available to aquatic

PRESENT WATER QUALITY CONDITIONS



life and limit the ability of the stream to support desirable species.

Plant nutrients like phosphorus and nitrogen which over-stimulate the growth of water plants that ultimately decompose and create disagreeable water tastes and odors.

Solids are all types of material, both suspended and dissolved, which collectively act to degrade water quality by their mere presence.

Pathogenic agents including viruses and bacteria which can cause dysentery, polio, intestinal disorders, skin diseases, etc., through water ingestion or contact.

All of these pollutants exist in the Merrimack River in immense quantities. In 1964, oxygen-demanding wastes were equivalent in strength to the untreated sewage of 1.4 million people. Desirable forms of water life in most reaches of the river are all but gone, and biological studies reveal that phosphate and nitrate concentrations are far in excess of the amount needed to produce objectionable algal blooms. Coliform bacteria counts, more than 1,800 times the levels considered minimally safe for human contact, have not been uncommon. Bad taste and odor problems plague public water supplies drawn from the Merrimack, even after extensive disinfection and conditioning.

Aesthetically, the Merrimack is hardly a river at all. And that is the real tragedy. The river is not so much a detriment as a nullity; it has been polluted for so many generations that people avoid it by habit and not by design. From the air, the Merrimack is a no-man's land barren of activity. Only short portions are safe for human contact and in some reaches the river is now suitable only for the transport of waste. There is no rapport possible with the water. Dangerous and offensive, the Merrimack has become a non-river.

THE SOLUTIONS

The purpose of all of the wastewater schemes (i.e., the current implementation program and the seven supplementary, alternative schemes) is to improve the river for all the services man and nature demand of it. The existing EPA-State program was designed to meet Federal-State instream standards for a specific set of uses along each stretch of the river. It makes provision for the treatment of municipal sewage, pretreated industrial waste and a very limited amount of stormwater flowing in combined sewers.

The explicit goal of the seven alternative schemes developed for this report is to restore the Merrimack to full health and productivity. First, cleanliness is an end by and of itself. But how clean is clean? For the purposes of this Feasibility Study, a clean Merrimack means "maximum feasible purity" or a removal of all those pollutants issuing from the major urban study areas that technology can treat. The notion is that this river should by rights be able to respond successfully to the most stringent quality demands anywhere along its entire length. Individuals, industry, and even the fish should be able to choose their encounter with the water rather than be confined to activity zones. With directed planning and a responsive public, these strategies make it possible to integrate water uses and create a single heterogeneous river community. In practical terms, the same gallon of water that runs through a home in Concord should be able to fertilize corn in Manchester, scour wool in Lawrence, and still quench a thirst downstream.

Far from being visionary, such cleanliness is within the capabilities of technologies already available. First, basic water treatment — primary and secondary processes — can remove 85% of biodegradable waste, 85% of suspended solids, and 99.9% of harmful bacteria. These techniques including treatment lagoons and the activated sludge process are well-established, widely understood, and can provide a measure of stream cleanliness which represents an impressive improvement over present water quality.

However, to control the full range of pollutants effectively, advanced treatment techniques must be applied. These are tertiary, physical chemical, and land renovation systems that use processes which take up where basic (secondary biological) treatment leaves off. Coagulation-sedimentation, carbon adsorption, filtration, and ion exchange all attack the remaining concentrations of common pollutants left after basic treatment and additional sophisticated substances which basic treatment does not affect:

Residual Pollutants	Biochemical Oxygen Demand (BOD) Suspended solids (SS) Chemical oxygen demand (COD) Pathogenic bacteria
Additional Pollutants	Nitrogen Phosphorus Total dissolved solids Heavy metals (at industry or advanced waste treatment facility) Refractory organics Viruses

Land application uses the vegetative cover and the soils beneath to trap constituent pollutants in overland flow and infiltrations areas.

With a complementary series of basic and advanced water treatment processes, color, odors, and bad taste are eliminated and the aesthetic appeal of the water can be fully restored.

Organized by water, land, and combination water-land oriented technologies all seven alternative wastewater management schemes have process components which deal with the major point sources of water pollution in the Merrimack Basin. Although they vary in process arrangements to offer a full spectrum of system options, all substantially achieve, the same goal-maximum feasible purity. The seven schemes also:

- Make specific provision for the transmission and treatment of all three types of urban wastewater; sewage; pre-treated industrial waste and stormwater up to 2.6 inches of rainfall in 6 hours.
- Integrate waste treatment services geographically at least within sub-regions and design for 1990 projected flows in the:

  Lowell-Lawrence-Haverhill Area, including Andover, Groveland, Methuen, North Andover, Billerica, Chelmsford, Dracut and Tewksbury.

  Fitchburg-Leominster Area, including Lunenburg and Westminster.

  Nashua Area, including Hudson and Merrimack.

  Manchester Area, including Bedford, and Goffstown.

  Concord Area, including Pembroke, Hooksett, Penacook, Suncook and Part of Bow.

  Winnipesaukee River Area, including Northfield, Franklin, Tilton, Sanbornton, Belmont, and Laconia.
- Supplement basic wastewater treatment by attacking residual pollutants resistant to the activated sludge process as well as nutrients, viruses, dissolved solids, refractory organics and some heavy metals.
- Include cost estimates which cover capital expenditures for construction, land, engineering and design fees, supervision and inspection, and contingencies as well as average annual costs for amortization of capital over 50 years 5⅜% interest, operation and maintenance, and major replacement of project features that may wear out in less than 50 years.
- Offer impact analyses which examine the ecologic, hygienic aesthetic, social, and economic changes which may be associated with implementation, e.g.,

  Land use planning
  Linkages between urban and rural environments
  Diversified industrial activity
  Increased agricultural productivity

A summary of the features of the EPA-State implementation program and the seven complementary wastewater management schemes follows, and is keyed to the fold-out map.

EPA-STATE IMPLEMENTATION PROGRAM

Selection Criteria:

- Applies well-established technologies
- Has institutional simplicity
- Represents minimal capital investment to satisfy existing regulations
- Places reliance on the assimilative cleansing capacity of the river
- Meets in-stream water quality criteria according to "reasonable judgment"

Design Criteria:

Designed for municipal, industrial, and very limited stormwater volumes projected to 1990

Treatment Components:

Basic:

▲ △ Fifteen activated sludge wastewater treatment plants, either completed, under construction, definitely proposed, or in preliminary planning (not including the Winnepesaukee River area)

Basic — Partially Advanced:

▲ One activated sludge wastewater treatment plant with carbon adsorption facilities planned at Fitchburg-West

Sludge disposal by sanitary land fill, or incineration

Estimated Capital Cost:
$235,000,000

Average Annual Cost:
$29,000,000

SCHEME NO. 1: DECENTRALIZED, WATER ORIENTED SYSTEM

Selection Criteria:

- Simplifies institutional arrangements
- Utilizes definitive portions of the current implementation program
- *Causes minimum disruption* of the natural streamflow regime of the Merrimack basin
- Achieves limited economies of scale (single advanced treatment systems for each major area)
- Takes advantage of advanced water oriented technology

Design Criteria:

Designed for municipal, industrial and stormwater volumes projected to 1990 (including a storm with 2.6" rainfall in 6 hours)

Treatment Components:

Basic:

▲ Ten activated sludge wastewater treatment plants with sludge digestion and dewatering facilities

Advanced:

Ⓣ Four regional tertiary wastewater treatment plants with sludge dewatering facilities

Ⓟⓒ Two regional physical-chemical wastewater treatment plants with sludge digestion and dewatering facilities

Ⓢ Ⓛ Ten subsurface storage chambers and five surface lagoons for temporary storage of stormwater and combined sewer flow

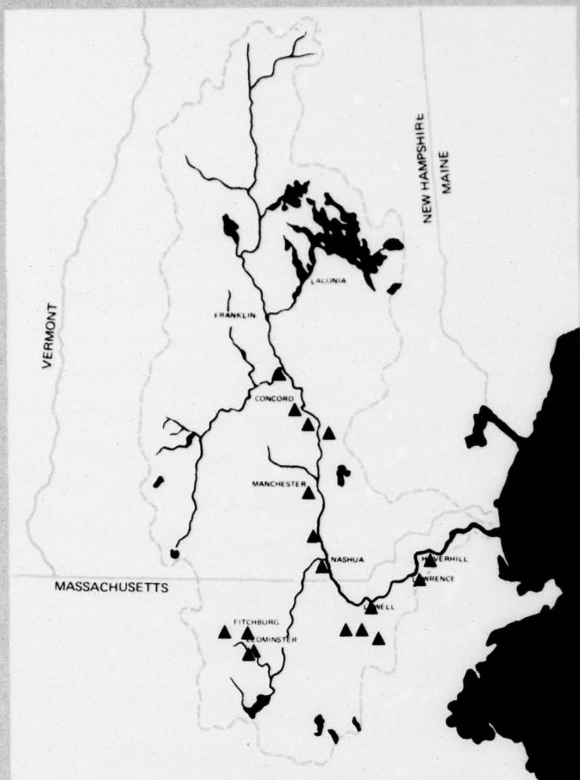
Approximately 129 miles of underground sewage transmission pipes and tunnels

Sludge produced by both basic and advanced treatment will be applied to farmlands proximate to each area

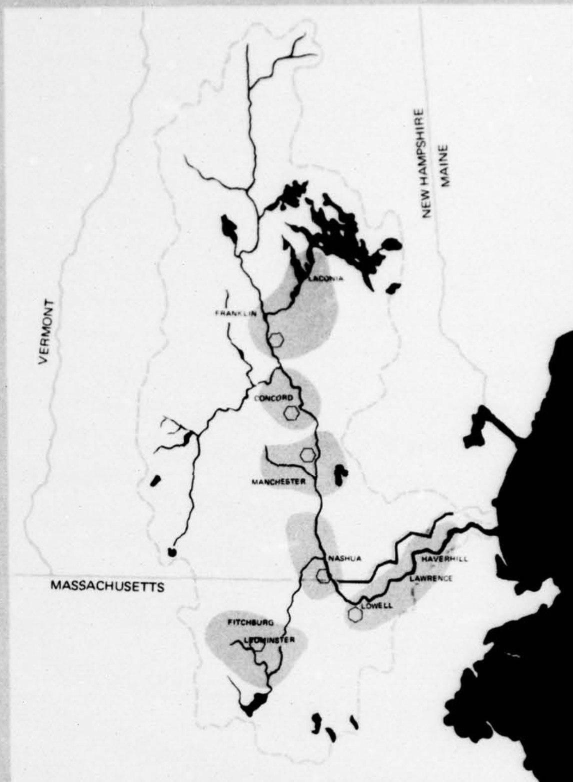
Brines will be evaporated, stored, and periodically disposed of at sea

Estimated Capital Cost:
$876,000,000

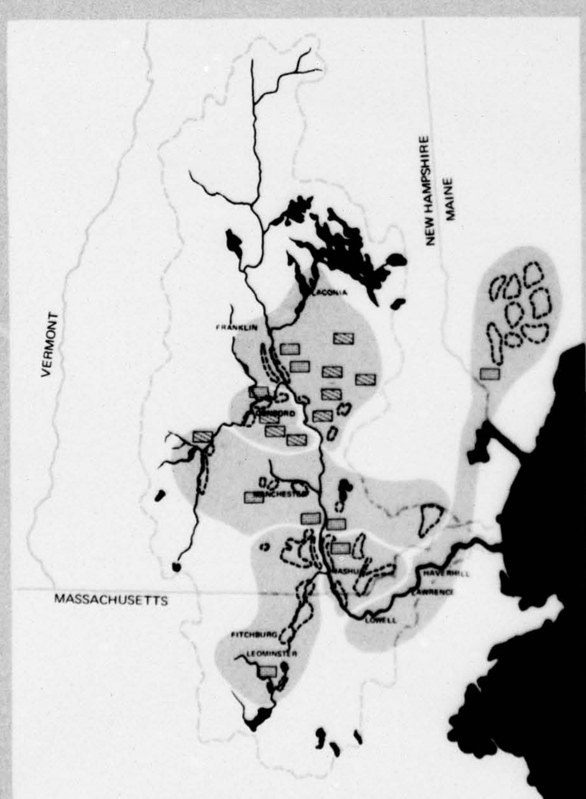
Average Annual Cost:
$96,000,000



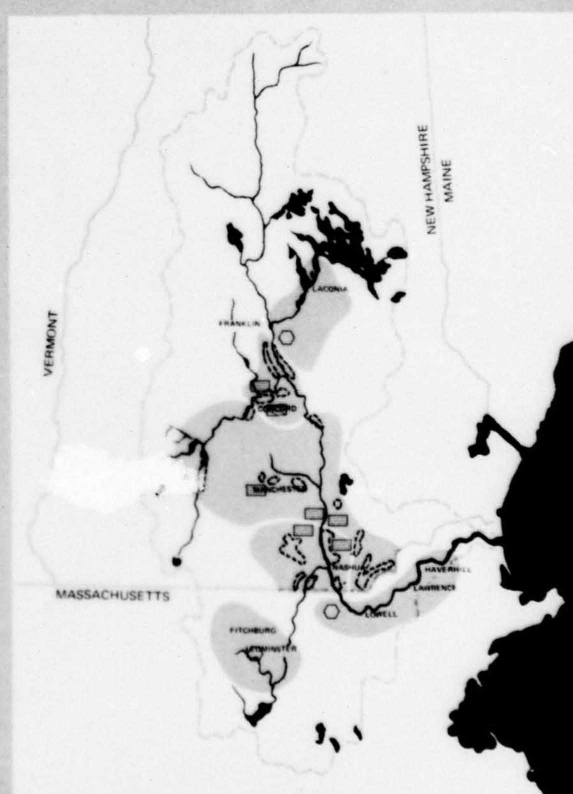
EPA STATE IMPLEMENTATION PROGRAM FOR WATER POLLUTION ABATEMENT



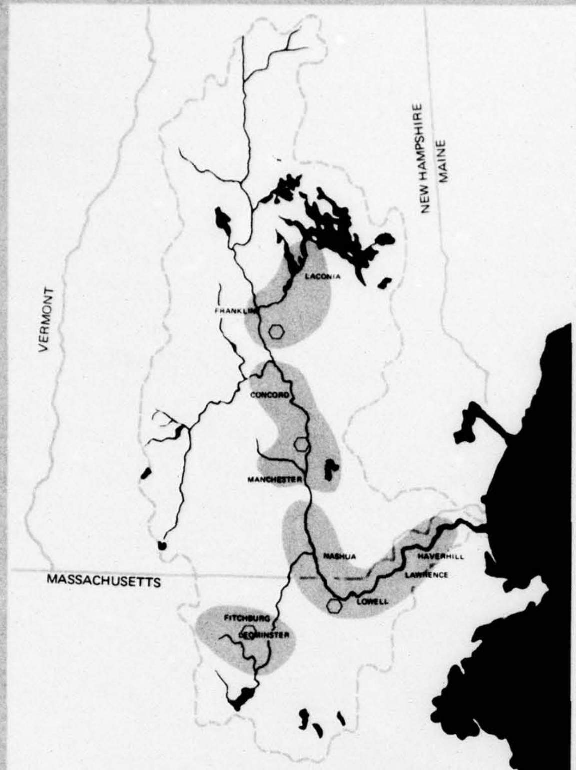
SCHEME NO. 1 – DECENTRALIZED, WATER ORIENTED SYSTEM



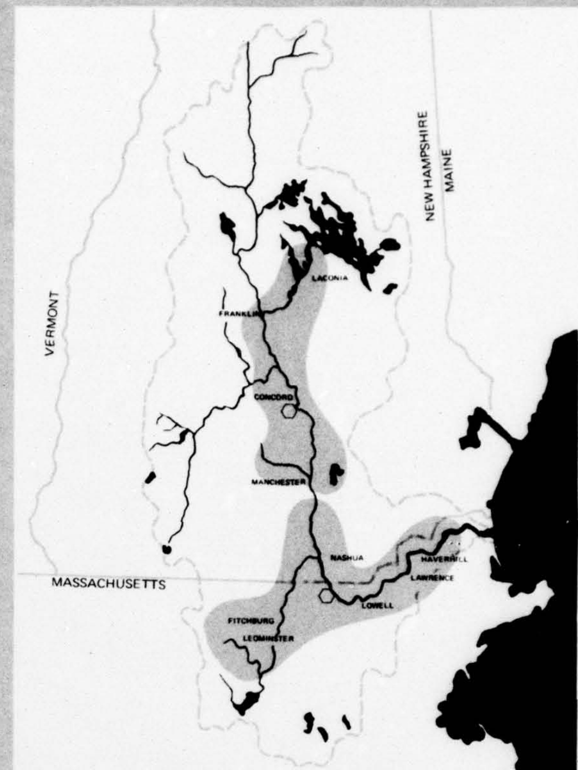
SCHEME NO. 4 – DECENTRALIZED, LAND ORIENTED SYSTEM



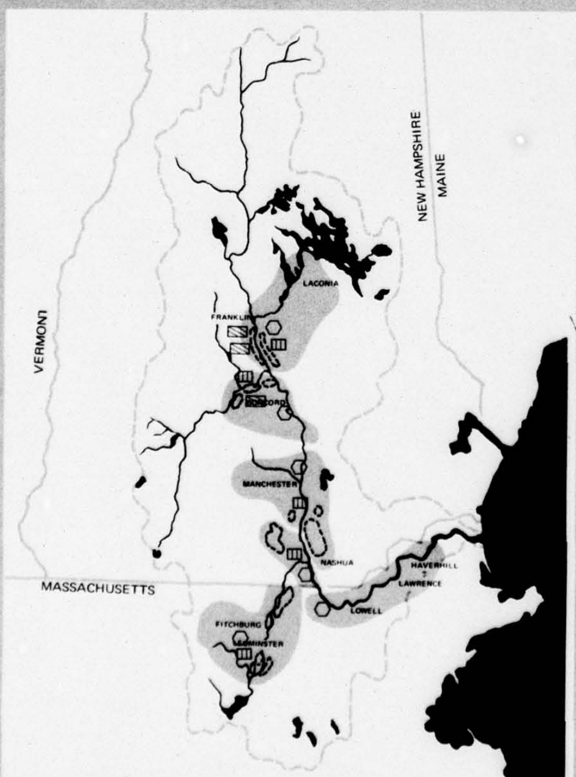
SCHEME NO. 5 – DECENTRALIZED, WATER AND LAND ORIENTED SYSTEM



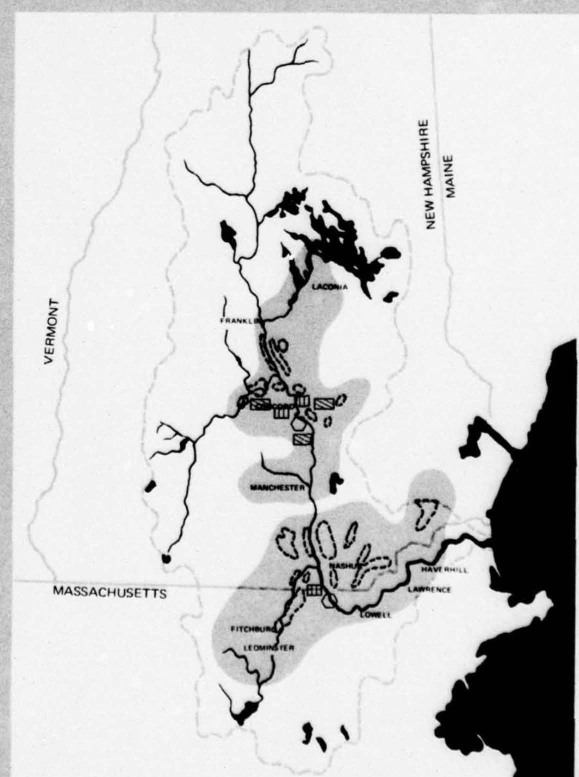
SCHEME NO. 2 – PARTIALLY DECENTRALIZED, WATER ORIENTED SYSTEM



SCHEME NO. 3 – CENTRALIZED, WATER ORIENTED SYSTEM



SCHEME NO. 6 – DECENTRALIZED – ALTERNATING, WATER–LAND ORIENTED SYSTEM



SCHEME NO. 7 – CENTRALIZED – ALTERNATING, WATER–LAND ORIENTED SYSTEM

SCHEME NO. 2: PARTIALLY DECENTRALIZED, WATER ORIENTED SYSTEM

Selection Criteria:

- Increases physical integration centralizing control over larger volumes of reclaimed wastewater
- Utilizes definitive portions of the existing implementation program
- Increases development opportunities between urban areas along the wastewater transmission routes
- Takes advantage of advanced water oriented technology

Design Criteria:

Designed for municipal, industrial and stormwater volumes projected to 1990 (including a storm with 2.6″ rainfall in 6 hours)

Treatment Components:

Basic:

▲ Ten activated sludge wastewater treatment plants with sludge digestion and dewatering facilities

Advanced:

Ⓣ Two regional tertiary wastewater treatment plants with sludge dewatering facilities

(PC) Two regional physical-chemical wastewater treatment plants with sludge digestion and dewatering facilities

Ⓢ Ⓛ Ten subsurface storage chambers and five surface lagoons for temporary storage of stormwater and combined sewer flow

Approximately 150 miles of sewage transmission pipes and tunnels

Sludge produced by both basic and advanced treatment will be applied to farmlands proximate to each area

Brines will be evaporated, stored, and periodically disposed of at sea

Estimated Capital Cost:
$877,000,000

Average Annual Cost:
$95,000,000

SCHEME NO 3: CENTRALIZED, WATER ORIENTED SYSTEM

Selection Criteria:

- Maximizes physical integration and economies of scale
- Uses alternative advanced water oriented technology
- Centralizes available reusable water
- Maximizes opportunities for regional cooperation among urban areas
- Maximizes development opportunities among urban areas along wastewater transmission routes

Design Criteria:

Designed for municipal, industrial and stormwater volumes projected to 1990 (including a 2.6″ rainfall in 6 hours)

Treatment Components:

Basic:

None

Advanced:

(PC) Two regional physical-chemical wastewater treatment plants with sludge incineration

Ⓢ Ⓛ Ten subsurface storage chambers and five surface lagoons for temporary storage of stormwater and combined sewer flow

Approximately 184 miles of underground sewage transmission pipes and tunnels

Sludge produced by advanced treatment facilities will be incinerated on-site

Brines will be evaporated, stored, and periodically disposed of at sea

Estimated Capital Cost:
$668,000,000

Average Annual Cost:
$74,000,000

SCHEME NO. 4: DECENTRALIZED, LAND ORIENTED SYSTEM

Selection Criteria:

- Utilizes wastewater nutrients in timber and crop production
- Preserves rural character of the landscape by protecting green space and preventing encroachment on the flood plain
- Allows basin-wide augmentation of summer streamflows
- Fully utilizes land application technology
- Maximizes development opportunities among urban areas with flexible treatment lagoon and transmission line siting

Design Criteria:

Designed for municipal, industrial and stormwater volumes projected to 1990 (including a 2.6" rainfall in 6 hours)

Scheme Components:

Basic:

Thirteen aerated wastewater treatment and storage lagoon areas

Advanced:

Approximately 8,360 acres of spray irrigation overland flow with recapture system for renovated water

Approximately 71,650 acres of spray irrigation infiltration with recapture system for renovated water

Ten subsurface storage chambers and five surface lagoons for temporary storage of stormwater and combined sewer flow

Approximately 216 miles of underground sewage transmission pipes and tunnels

Approximately 365 miles of effluent distribution pipes and tunnels to irrigation areas

Sludge produced in the course of treatment will be anaerobically digested and applied to farmlands proximate to each area

Estimated Capital Cost:
$1,108,000,000

Average Annual Cost:
$88,000,000

SCHEME NO. 5. DECENTRALIZED, WATER AND LAND ORIENTED SYSTEM

Selection Criteria:

- Offers mixed land and water oriented technologies
- Utilizes many definitive portions of the current implementation program
- Eliminates use of land outside the Merrimack Basin
- Partial utilization of wastewater nutrients in timber and crop production
- Partial preservation of rural character through protection of green space and the flood plain

Design Criteria:

Designed for municipal, industrial and stormwater volumes projected to 1990 (including a 2.6" rainfall in 6 hours)

Scheme Components:

Basic:

▲ Six activated sludge wastewater treatment plants with sludge digestion and dewatering facilities

Six aerated wastewater treatment and storage lagoon areas

Advanced:

Two regional tertiary wastewater treatment plants with sludge dewatering facilities

One regional physical-chemical wastewater treatment plant with sludge digestion and dewatering facilities

Approximately 1400 acres of spray irrigation overland flow with recapture system for renovated water

Approximately 25,940 acres of spray irrigation infiltration with recapture system for renovated water

Ten subsurface storage chambers and five surface lagoons for temporary storage of stormwater and combined sewer flow

Approximately 165 miles of underground sewage transmission pipes and tunnels

Approximately 117 miles of effluent distribution pipes to irrigation areas

Sludges produced in the course of treatment will be anaerobically digested and applied to farmlands proximate to each area

Brines will be evaporated, stored, and periodically disposed of at sea

Estimated Capital Cost:
$957,000,000

Average Annual Cost:
$94,000,000

SCHEME NO. 6: DECENTRALIZED-ALTERNATING, WATER-LAND ORIENTED SYSTEM

Selection Criteria:

- Utilizes mixed water-land oriented technologies
- Substitutes treatment plants from the definitive implementation program for treatment lagoons
- Minimizes land requirements
- Helps preserve rural character by protecting green space and preventing encroachment on considerable portions of the flood plain
- Utilizes a portion of the nutrients in wastewater on timber and crop land
- Improves treatment reliability through back-up systems

Design Criteria:

Designed for municipal, industrial and stormwater volume projected for 1990 (including a 2.6" rainfall in 6 hours)

Treatment Components:

Basic:

▲ Ten activated sludge wastewater treatment plants with sludge digestion and dewatering facilities

Advanced:

Four regional tertiary wastewater treatment plants with sludge dewatering facilities

Two regional physical-chemical wastewater treatment plants with sludge digestion and dewatering facilities

Approximately 2,900 acres of spray irrigation overland flow with recapture system for renovated water

Approximately 21,720 acres of spray irrigation infiltration with a recapture system for renovated water

Ten subsurface storage chambers and five surface lagoons for temporary storage of stormwater and combined sewer flow

Five surface holding lagoons for temporary storage of partially treated wastewater

Approximately 129 miles of underground sewage transmission pipes and tunnels

Approximately 88 miles of effluent distribution pipes to irrigation areas

Sludge produced by both basic and advanced treatment will be applied to farmlands proximate to each area

Brines will be evaporated, stored, and periodically disposed of at sea

Estimated Capital Cost:
$996,000,000

Average Annual Cost:
$96,000,000

SCHEME NO. 7: DECENTRALIZED-ALTERNATING, WATER-LAND ORIENTED SYSTEM

Selection Criteria:

- Utilizes mixed technology for all areas; land requirements met totally within the basin
- Maximizes development opportunities among urban and rural areas vía wastewater transmission routes
- Maximizes economy of scale in the water oriented portion of the system with use of wastewater nutrients on the land
- Maximizes opportunities for regional cooperation

Design Criteria:

Designed for municipal, industrial and stormwater volume projected for 1990 (including a 2.6″ rainfall in 6 hours)

Treatment Components:

Basic:

None

Advanced:

Two regional physical-chemical wastewater treatment plants with sludge incinerators

Approximately 2,400 acres of spray irrigation overland flow with recapture system for renovated water

Approximately 36,050 acres of spray irrigation infiltration with a recapture system for renovated water

Ten subsurface storage chambers and five surface lagoons for temporary storage of stormwater and combined sewer flows

Three surface holding lagoons for temporary storage of partially treated wastewater

Approximately 184 miles of underground sewage transmission pipes and tunnels

Approximately 115 miles of effluent distribution pipes to irrigation areas

Sludge produced by advanced treatment facilities will be incinerated on site

Brines will be evaporated, stored, and periodically disposed of at sea

Estimated Capital Cost:
$843,000,000

Average Annual Cost:
$78,000,000

The Estuary

Photos by Aerial Photos of New England, Inc.

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ATLANTIC OCEAN
BOSTON HARBOR
GREAT BAY
FALLS RIVER
ROCHESTER
BERWICK
SOMERSWORTH
DOVER
PORTSMOUTH
PITTSFIELD
BRADFORD
PENACOOK
MERRIMACK RIVER
RIVER
PENACOOK LAKE
CONCORD
HENNIKER
SUNCOOK RIVER
PEMBROKE
SUNCOOK
HILLSBORO
HOOKSETT
GOFFSTOWN
PISCATAQUOG RIVER
MANCHESTER
CONTOOCOOK RIVER
HANCOCK
DUBLIN
BEDFORD
MASSABESIC LAKE
KINGSTON
AMESBURY
PETERBOROUGH
MERRIMACK
LONDONDERRY
DERRY
ISLAND POND
ARLINGTON MILL RESERVOIR
WILTON
WINDHAM
SALEM
CANOBIE LAKE
HAVERHILL
MERRIMACK RIVER
NEWBURYPORT
SOUHEGAN RIVER
PENNICHUCK POND
LITCHFIELD
JAFFREY
GREENVILLE
COBBETTS' POND
SPICKETT RIVER
HUDSON
NASHUA
LAWRENCE
NEW HAMPSHIRE
MASSACHUSETTS
LOWELL
ANDOVER
ASHBURNHAM
PEPPERELL
FITCHBURG
LUNENBURG
NASHUA RIVER
SHAWSHEEN RIVER
CHELMSFORD
WESTMINSTER
NORTH NASHUA RIVER
AYER
FT. DEVENS
CONCORD RIVER
BILLERICA
LEOMINSTER
BEDFORD
CLINTON
MAYNARD
HUDSON
HOLDEN
WACHUSETT RESERVOIR
MARLBOROUGH
WAYLAND
BOSTON
SUDBURY RESERVOIR
NORTHBORO
WESTBORO
BROOKLINE
FRAMINGHAM
NORTH
GRAPHIC SCALE
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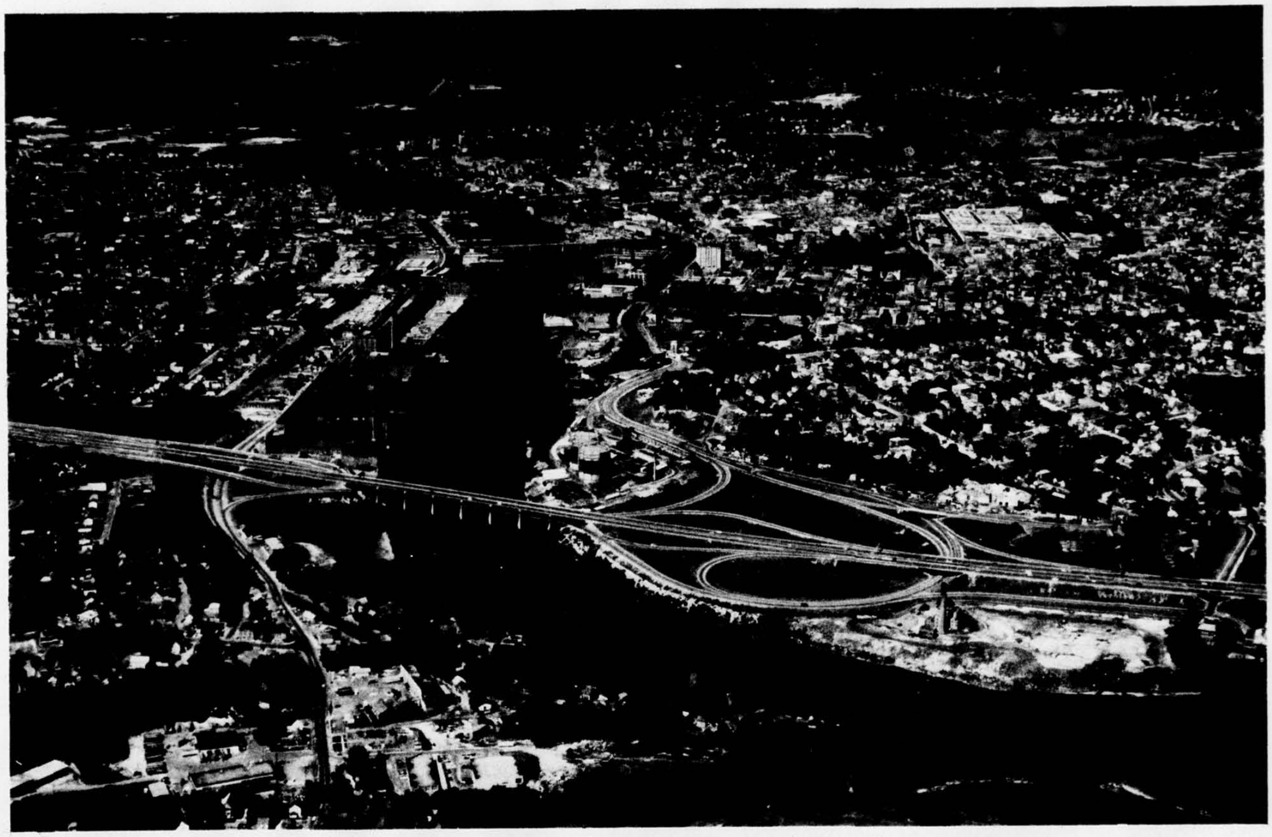


The lower basin

PHYSICAL DESCRIPTION

A river basin in its simplest terms is two things — the water of the river itself and the land it drains. It is a hydrologic unit which obeys the flow regimes established by nature and which in turn dictate the quantity of water in the mainstream and its many tributaries. Like a political entity, it has boundaries, dimensions, and constituents.

Accordingly, the Merrimack River Basin can be characterized with vital statistics. It lies in southeastern New England, chiefly in the State of New Hampshire and the northeast corner of Massachusetts. The Basin is 134 miles long north to south and up to 68 miles wide east to west, covering a land area of more than 5,000 square miles. The mainstream of the Merrimack River is formed at Franklin, New Hampshire, by the confluence of two smaller rivers; the Pemigewasset, rising under the granite chin of the Old Man of the Mountain, and the Winnipesaukee River which flows from the lake of the same name. It is New England's fourth largest river and drains an area having moderately warm summers, cold winters, and ample, evenly distributed rainfall.

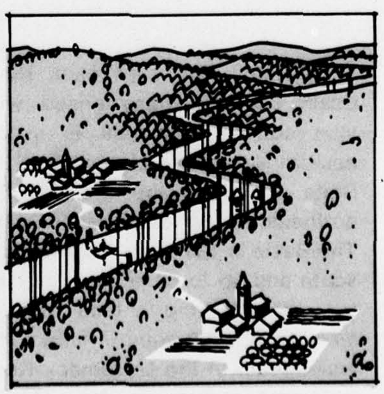
The country in most of the basin has an uneven hummocked look with an occasional peak standing out above the rolling hills and gently sloped valleys. In the far north above Plymouth lies the White Mountain National Forest, a rugged mountain terrain with narrow valleys where less than one percent of the thin stony soil is open land. In the central part of the Basin, the area covered by Belknap, Merrimack, and Hillsborough Counties, the high ground gives way to moderate elevations and a wider flood plain along the main stem of the Merrimack and its large tributaries like the Contoocook and the Suncook. Here the soil is more accommodating and agricultural activity includes truck farming, dairying, and poultry produced for the Boston market. The southernmost portion of the Basin has rolling hills and irregular slopes. Soils are both stony and sandy, but nearly twenty percent of the total land area is in crops or open pasture.

The entire Basin bears the marks of the last glacial age. As a colossal sheet of ice ground across the face of New England toward Cape Cod, it gouged out depressions like Lake Winnipesaukee and carried along with it piles of jumbled rock and soil as glacial till. When the climate finally warmed and the ice withdrew from the Basin, the sea advanced inland, and formed the mouth or estuarine part of the river. Then the forest took root — spruce, birch and aspen to the north and red, white and pitch pine in the south.

THE HISTORY

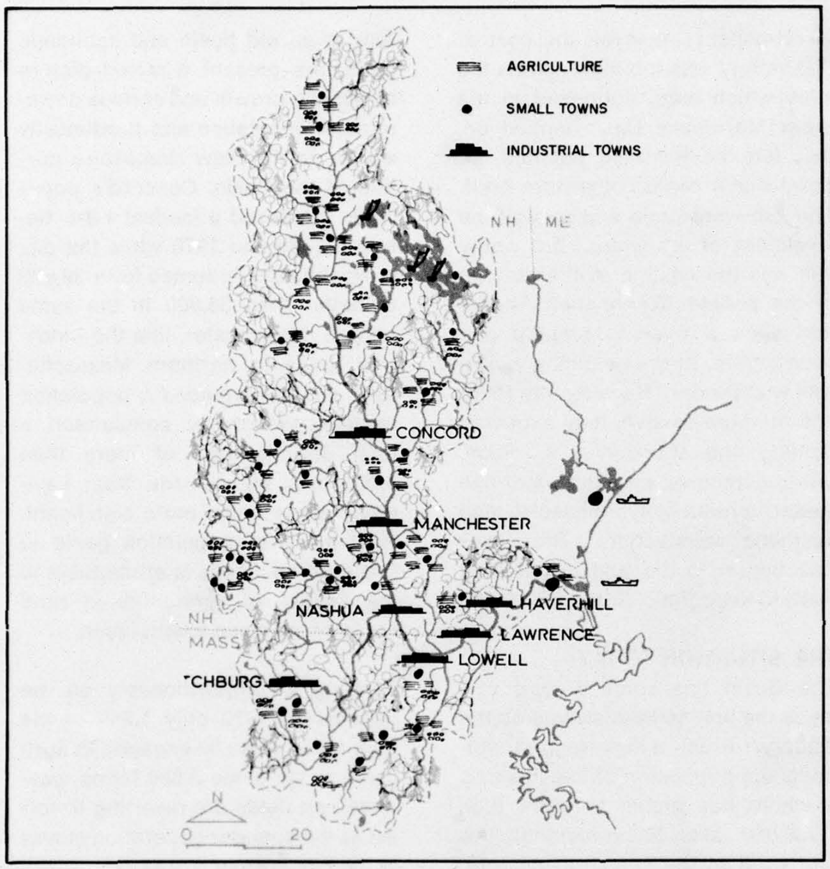
In the time when the forest was everywhere, the River ran unimpeded to the sea. Undistinguished because then beauty was no exception, it was called merely "swift water place" or Merrimack. Before the white man came in great numbers, the River was generous in its bounty. Hunters could take salmon, perch, herring, sturgeon and shad, clams and blue-mussels, fur-bearers and venison. The Redman and the River lived in harmony because the power of the water was insuperable, and it supplied the very essentials of life itself, food, drink, and free passage.

But this same wilderness was the sworn enemy of the Pilgrim. Armed with the plow and the rifle, white men began in earnest to subdue the Earth. At first, the early settlers depended on the Merrimack for sustenance even as the Indian did because their toehold in the New World at Newbury on the estuary was tenuous at best. But soon, with stores laid up in their barns, the hardiest of the lot struck out into the hinterlands along the river highway. The Merrimack was then the only continuum of open space available — a corridor along with explorers and trappers could move into the interior and lay out the sites of future settlements. During the colonial epoch of the seventeenth and eighteenth centuries, a steady stream of New England pioneers moved upward into the Basin. Once on their way, the people took from the River whatever they needed and prospered.


Colonial epoch landscape


Colonial epoch riverscape

As the trading posts became "civilised townes" fields began to open on the banks of the Merrimack and the forest cover was pushed back to make room for agriculture. Farms provided food and fibers in ample supply and life in the settled portion of the valley moved from subsistence levels to relative prosperity.



Industrial epoch

Industrial epoch riverscape

The soil was hard, but the people were tougher still, and soon there were stone walls to mark the boundaries between neighbors. On the river, *fishing became a major industry.* Anadromous species like the Atlantic salmon returned every year from the sea to spawn in the upper reaches of the Merrimack. So abundant was the salmon, in fact, that apprentices' contracts stipulated that they could not be made to eat it more than three times a week. The sturgeon fishery was also important in colonial times, the Merrimack being known as one of the two best sturgeon areas on the Atlantic seaboard. In the Boston market, pickled sturgeon brought ten shillings a keg in 1656, and even as late as 1887 two tons were taken from the river in one August week. And then there were no more. In the summer of 1969, a bloated sturgeon carcass floated ashore at Plum Island and even the old-timers were surprised.

Industrial epoch landscape

The salmon runs lasted until the mill dams came to the Merrimack Valley. The demands for water power to turn the wheels of the textile plants were the beginning of a new epoch for the river-industrial development. In the early nineteenth century entrepreneurs bought up the land along both sides of the river at Manchester, Lawrence, and Lowell and built dams to power what would become the premier textile works in America. These were company towns; the land, the workers, and the houses they lived in and even the water itself were all corporate property. The Essex Company, for one, flourished and by 1850 Lawrence and Lowell were the wool spinners and worsted manufacturers to the Nation.

But for the River, industrial success meant destruction. No longer a shining thread that the people depended upon for survival, by the turn of the twentieth century, the Merrimack had become a foul sluiceway carrying unimaginable burdens of human and industrial filth to the sea. Now only its motive force was needed and an entire water-oriented economy turned to manufactures. The Industrial Revolution and its psychology of dominion permanently altered the balance between the integrity of Nature and the disruptive potential of the human species. With new tools and new aspirations, men at last had conquered the water.

In retrospect, however, the cost of that victory was too high. When the mills which once flourished in the lower Merrimack Basin moved on, they left the River so polluted, so spent that it could not restore itself. The fish were gone and so was the loveliness of the water. But worse still was the change in the attitude of the people. Where their fathers had seen a river to respect and even revere, they saw only a worthless wastewater. Because the River had no more to give, they expected nothing and abandoned it. Soon, few remembered what the water had meant; productivity, pleasure, and aesthetic satisfaction. The River had begun to die and towns built walls to keep the children away.

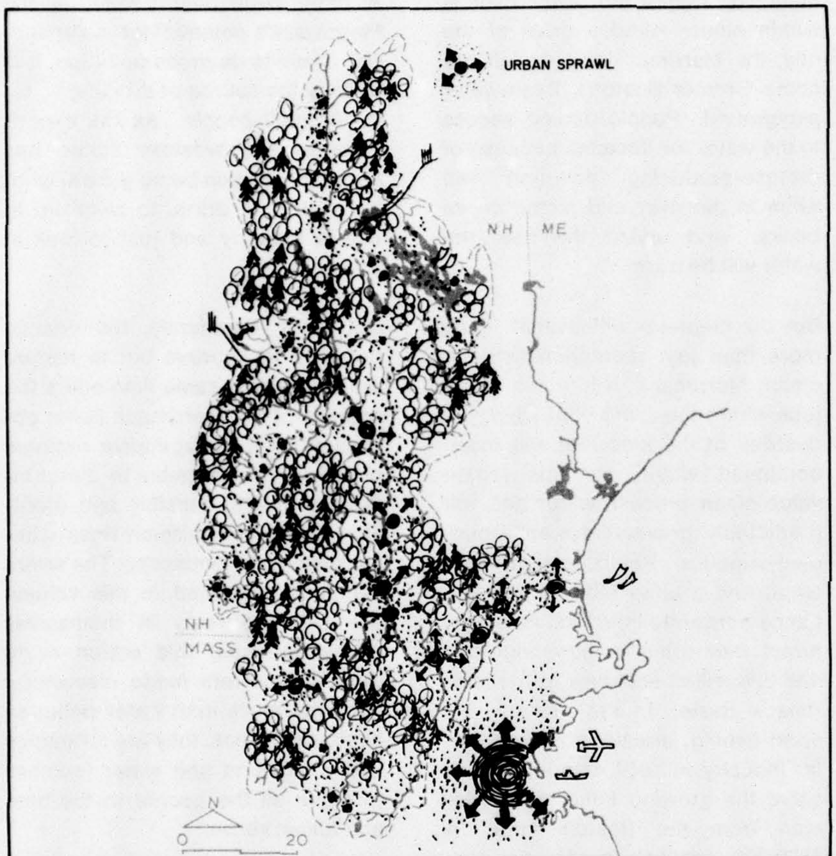
THE SITUATION TODAY

The Basin has come a long way since the first settlers arrived on the estuary. From a few ragged outposts the population of the Basin as a whole has grown to more than 1,250,000. Most Basin residents live and work in the industrial centers; Concord, Manchester, and Nashua in New Hampshire or Fitchburg-Leominster, Lowell, Lawrence, and Haverhill in Massachusetts. In these intensively developed urban areas in both states manufacturing operations predominate; textiles, leather goods, machinery, paper, plastics, metal plating and electronics. In non-urban areas, the bulk of economic activity is related to an increasingly important recreation industry in the extreme north and in the Merrimack River Estuary.

This is an old basin and economic indicators present a mixed picture of relative growth and serious downturns in population and productivity levels. In the New Hampshire portion of the Basin, Concord's population increased a modest 1.8% between 1960 and 1970 while the city of Nashua mushroomed from 39,000 to better than 55,800 in the same period. Manchester, like the industrial areas in northern Massachusetts has experienced a population decline, though by comparison a total out-migration of more than 4,700 over the decade from Lawrence alone is far more significant. How much of population gains in Basin urban places is attributable to the eclipse of agriculture in rural areas bears close examination.

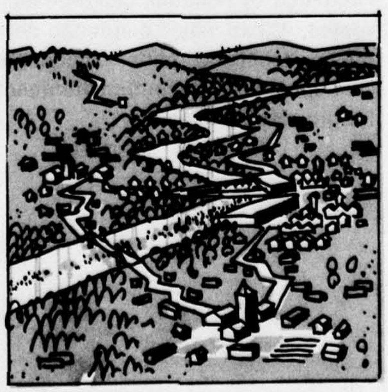
Farming is unquestionably on the decline; in 1970 only 1.2% of the population was still engaged in agriculture. On some 3,600 farms, pastures and fields are reverting to forest as the younger generation moves to the city in search of work.

Increasingly however, traditional "wet process" industries in the urban centers are unable to absorb the available labor supply and have fallen on hard times.



Today's problem

Today's riverscape



Today's landscape

Statewide unemployment figures for New Hampshire show alarming increases between July 1970, and June 1, 1971; 2,650 jobs lost in electrical products, 2,150 in leather, and 1,400 jobs eliminated in textiles. By comparison with the National joblessness rate of 6.5%, though, Manchester, Nashua, and Concord fare well at 5.2%, 5.0%, and 4.4% respectively. In Massachusetts the picture is less reassuring. In Lowell, for example, the unemployment rate has risen in one year from 6.5% to 11% and more than 7,500 are out of work. Consistent with that trend are rate increases of 3.1% in Worcester County (Fitchburg-Leominster area) and 2.8% in Lawrence-Haverhill. In short, the mills have been laying off, and not hiring. "For Sale or Rent" signs are beginning to appear in downtown store windows and the economy of the region, like the river behind its dams has lost much of its momentum.

POTENTIALS FOR ACHIEVEMENT

But what if it were clean? The generations who thought the Merrimack useless and then hopeless are passing away; and those concerned with the future of the Basin now see in a healthy river tremendous economic and social potential. The old values that once gave the River a unique place in the life of the region are gaining ground. Taxpayers ask, "Why not clean water?" "Why not here?" "Why not now?" It is no longer enough to neutralize the Merrimack's threat to public health or to screen its offensiveness from the public eye. Because the River may have to be the source of this region's future water supply, cleanliness is an imperative that cannot be ignored. This River must be improved out of necessity, if not out of principle.

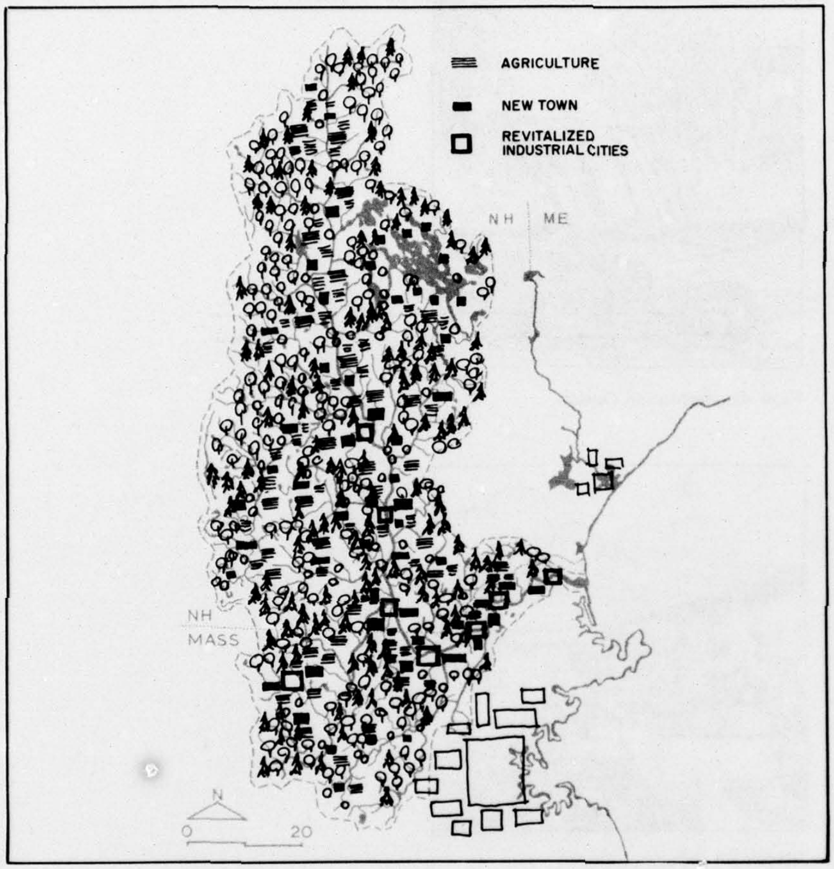
But would a clean river make any difference? What could it mean to the people of the Basin? First, a higher water quality could create significant improvements in the ecological balance of the River community. As the ability of the water to support aquatic life returned, desirable species of food and game fish would thrive in the Merrimack. Striped bass, and even the salmon could return, if the dams were removed or fish ladders added or improved. Recreational activity both for local residents and water-hungry travelers could increase dramatically. Since the lower river is within ninety minutes drive of the city, the Merrimack might well become Greater Boston's fresh-water playground. People denied access to the water for decades because of disease-producing pollution will swim in the river and picnic on its banks. And unlike the sea, the water will be warm.

But the clean-up will benefit many more than just recreationalists. A clean Merrimack will mean more jobs where there are none now. Industries of the kind that will mean continued vitality for this region value clean process water and will predictably gravitate toward abundant supplies. Realizing that clean water and a large labor supply enhance corporate interests, manufacturers can bring a more vigorous and diversified economy to the Merrimack Basin. In the estuary, the sport fishing, already a million dollar industry in 1964, can expand to serve the growing influx of sportsmen from the Boston Area. A $500,000 shellfish crop now contaminated by pollution could be harvested. Clean water can mean new public facilities, better municipal services, and a decent environment for growing families.

A more immediate benefit is the Merrimack's potential for water supply. Despite its gross pollution, it is already the source of drinking water for 200,000 people. As the experience of the Western states has shown, there can be no growth without water; to drink, to swim in, to use in industry and just to look at and enjoy.

But most importantly, the chance not only to improve but to restore the river at the same time offers the citizens of the Merrimack Basin opportunities for imaginative regional planning. It is possible to direct industrial growth sensibly and profitably along transmission lines without ruining the landscape. The seven solutions presented in this volume are planning tools in themselves which can help this region avoid the costly errors made elsewhere. They are more than water pollution abatement plans, they are strategies that bring land and water together to serve all the people in the best and fullest sense.

All seven alternatives offered in this report are technically feasible. Once implemented, in a few years any one of them could essentially renew the river and return impressive benefits on the public's investment. Specifically, the alternative treatment systems suggested in Chapter 1 and detailed in Chapter 4 allow at least five major water uses not now associated with wastewater management:



Potential for tomorrow

Tomorrow's riverscape

Tomorrow's landscape

(1) *Flow augmentation:* to recycle reclaimed water through selected sections of the river would reduce low-flow periods and insure a steady and attractive stream flow

(2) *Water supply:* direct use of super-clean treated water to meet municipal and industrial demands

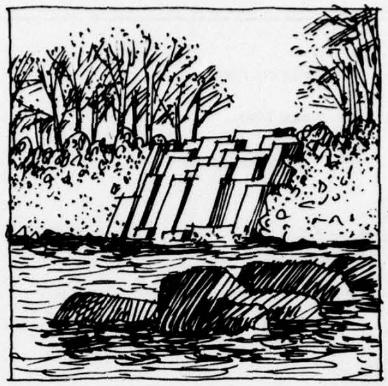
(3) *Irrigation:* application of treated wastewaters rich in nutrients on crops and timber cover to revitalize agricultural activity

(4) *Restoration of river quality:* introduction of pure water into now-degraded streams to rapidly increase overall quality to allow total recreational use

(5) *Construction of recreational water bodies:* use of treated wastewater to provide new water bodies for leisure-time activities.

But perhaps most important is the potential for the renewal of the deep aesthetic, that intimacy between man and the river which has been absent so long. Riverside esplanades with concert shells could replace the junkyards. Marinas complete with fine restaurants might revitalize decayed urban waterfronts, and bring people back to the water's edge. Even the mechanics of water treatment could become assets to the local landscape. For example, an imaginative design for flow augmentation might create a *series of urban waterfalls to cool* and clean downtown air and serve as a focal point for year-round rivershore activity. As privacy and freedom in the macadam environment of the city become scarce, the restoration of the Merrimack's open space seems all the more crucial.

All these things the Merrimack could do if only it were restored. Chapter 3 describes the technologies that can undo the harm of existing pollution and complete the job of water quality management begun by EPA and the States.



Flow Augmentation Outfall

Riverfront redevelopment

A clean Merrimack promises the citizens of the Basin, and indeed of all New England, outstanding opportunities for healthy economic development and environmental restoration. This river could produce harvests of finfish and shellfish. It could become the source of abundant municipal water supplies. Industries excluded before because they required clean process water could revitalize and diversify Basin manufacturing. The New England farm could be saved from extinction. And most importantly, a clean river can make the Merrimack Valley a decent, spacious place in which people from every walk of life could work and raise their families.

That is the promise. But, can it become a reality? The reply of the Task Force assembled to find answers to that question is a qualified "Yes." Beginning with the EPA-State implementation program and from a strictly technical point of view, maximum feasible water purity can be achieved in the Merrimack River. Any one of the seven illustrative schemes discussed in Chapter 4 could essentially renovate the water flowing in the mainstream within a few years after its completion. The technologies, the know-how and the manpower required to do the job are ready now.

POLLUTANTS

The environment we live in is like a house. When the house is tidy, it functions smoothly and the people inside can live easy, unrestricted lives. When the house is poorly managed and becomes disorderly, however, its inhabitants are uncomfortable and their life style is constrained and tense.

In that analogy the clutter in the environmental house is pollution. Pollutants are simply substances which do not belong where they are now. Individually they need not necessarily be harmful, but in great quantities or in combination they upset the workings of the natural biochemical processes which "houseclean" the Earth and make survival for the human species possible. Pollutants come in many forms: organic, bacterial, inorganic, dissolved, colored, etc. Uncontrolled, they can contaminate the land, the air or the water and make them unfit for the constructive uses to which men and other creatures might put them.

The origin of pollutants which attack the quality of ground and surface waters fall into three broad classes:

- Domestice Sewage
- Industrial Wastes
- Stormwater

Domestic sewage is water which has been used for ordinary household purposes like laundering and bathing or to carry away human wastes. In most urban areas, it flows from home plumbing systems into sub-surface collection lines which carry it to treatment plants or, all too often, directly into the nearest natural body of water. It is heavily organic, though the introduction of synthetic detergents has given domestic sewage some of the characteristics of industrial waste.

Water-borne pollutants also emanate from industry as by-products of manufacturing processes. Typically, they can be organic wastes from food processing or inorganic waste supplied by mineral substances as varied as the fabrication techniques which produce them.

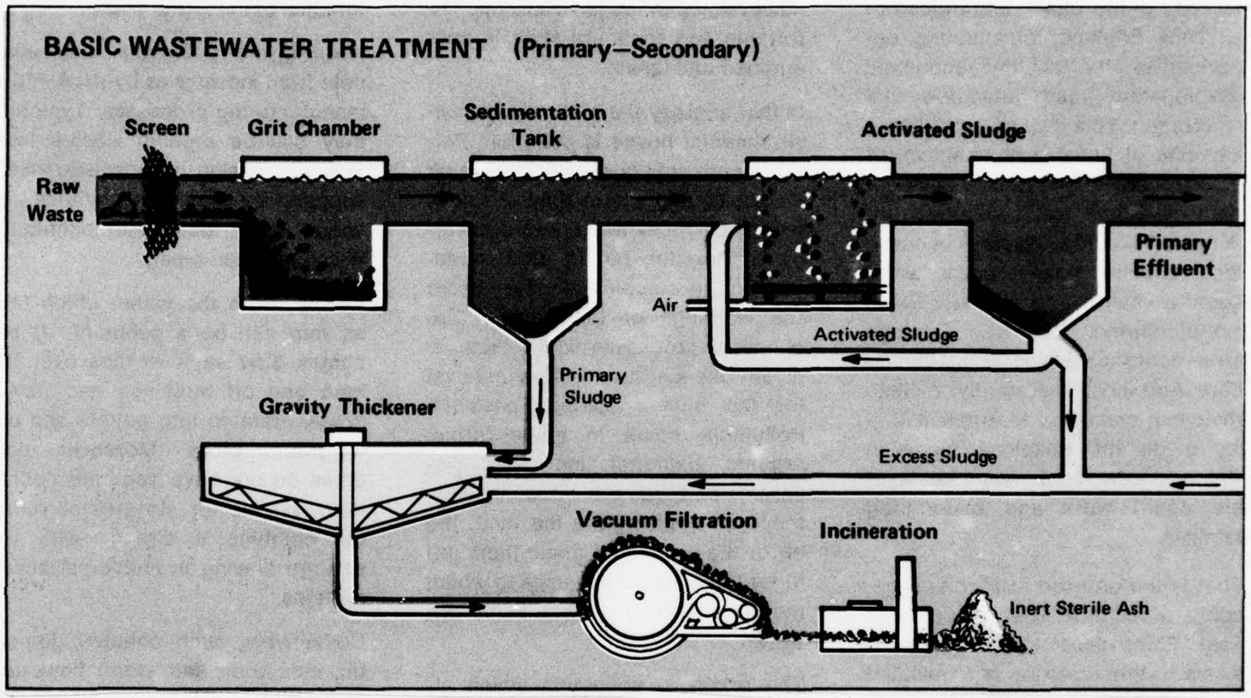
Finally, even the water which falls as rain can be a pollutant. It becomes dirty as it washes over the land and off buildings and paved areas, draining into gutters and underground pipes. Moreover, most cities do not have separate collection systems for stormwater runoff but combine it directly with the sewage flowing in municipal sewer systems.

Collectively, such polluted domestic, industrial, and storm flows are called wastewater. To prevent environmental damage, wastewater should be treated to remove pollutants or at least render them harmless before they are discharged into receiving waters. In a river system, it is the nature and quantity of the pollutants which determines the dimensions of a water pollution problem and the techniques best applied to abate it.

In the Merrimack Basin wastewaters contain four general types of pollutants: 1) oxygen-demanding wastes; 2) nutrients; 3) solids; and 4) pathogenic agents.

Oxygen-Demanding Wastes

Organic materials are found in domestic sewage and industrial wastes



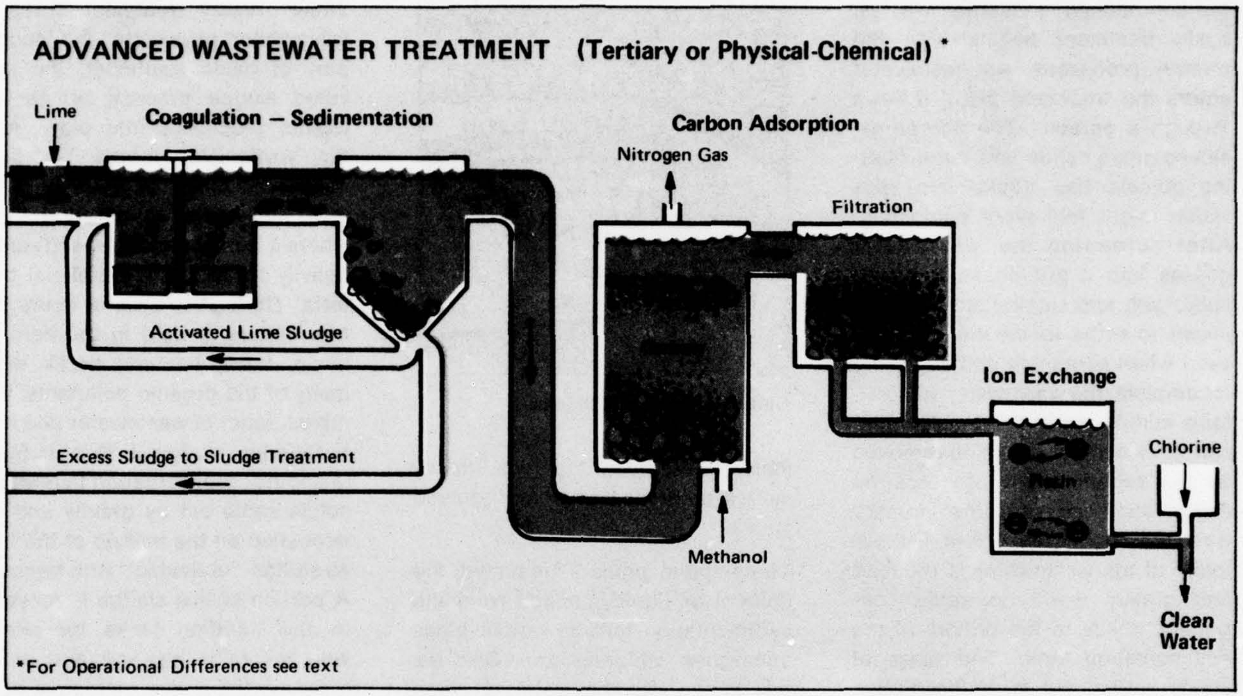
of plant and animal origin. In this Basin, manufacturing processes like paper production, tanning and textiles are particularly heavy contributors of organic contaminants. These wastes are measured in terms of biochemical oxygen demand (BOD), or the amount of oxygen necessary for bacteria to consume organics in the natural biological cleansing process. In addition to readily biodegradable wastes, refractory organics representing an additional oxygen depletion requirement still remain. The measurement of these strengths as chemical oxygen demand (COD) is related again to oxygen consumption, this time by a laboratory chemical reaction. However, the refractory or stubborn nature of these organic chemicals precludes their rapid chemical breakdown in nature. Because fish and other aquatic organisms must compete with oxygen-demanding wastes for enough oxygen to sustain life, dissolved oxygen BOD and, to a lesser extent COD levels are critically important to a healthy stream community.

Nutrients

Nitrogen and phosphorus are the two principal polluting nutrients. Added to wastewater through large amounts of domestic sewage, industrial wastes and runoff from fertilized land, they are excellent examples of too much of a good thing in the wrong place. They are essential to plant life, but in excess quantities, they can over-stimulate growth of algae and aquatic plants. These so-called "blooms" of algae are aesthetically unpleasant and can cause severe oxygen demand as well as taste and odor problems.

Solids

A wide variety of materials entering wastewater flowing from manufacturing processes, agricultural practices, and weathering of natural sources are referred to as solids. These solids can be "suspended" or "dissolved" depending on wheth-



er or not they can be trapped on a filter. Dissolved solids, or those which pass the filter, consist generally of inorganic minerals. If the concentration of these solids becomes too high, the water becomes unacceptable as a water supply source because of its laxative effect on humans, its residue left in industrial processes, and its toxicity to agricultural products. Solids retained on filters are "suspended" and in excessive amounts can cause degradation of water quality by coloring the water or by ruining the bottom habitat of the watercourse by prohibiting primary food production for fish.

Pathogenic Agents

In this category are the disease-producing virus and bacteria which are introduced to surface and ground water by domestic sewage and by certain kinds of industrial processes like tanning and meat packing. Pollution levels for pathogens can be measured in terms of indicator organisms called coliform, the bacteria commonly present in the intestines of warm-blooded animals.

PROCESSES

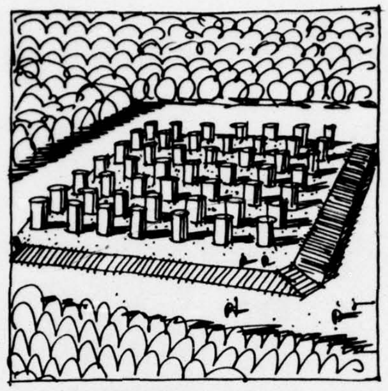
To deal with this ever-increasing number of pollutants, technology has developed a range of individual treatment processes designed to address different components of a wastewater pollution problem. No single process can do the whole job. But together, combined into wastewater management systems, they can produce effluent of better quality than the water we drink every day. To make the explanation of each of the schemes in Chapter 4 more easily understood, the following discussion of water renovation techniques is organized into water oriented and land oriented approaches.

Water Oriented Processes

Basic Processes:

For domestic sewage and many

pre-conditioned industrial wastes, basic treatment begins with the primary processes. As wastewater enters the treatment plant, it flows through a screen. The screen removes gross solids and large floating objects like sticks and rags which might foul plant equipment. After screening the wastewater passes into a grit chamber where sand, grit, and small stones are allowed to settle to the bottom. But even when screening and degritting is complete, the wastewater still contains minute particles of suspended solids. This material can be removed by the sedimentation process, the major component of the primary treatment operation. Here the velocity of the wastewater is reduced and gravity works to settle suspended solids to the bottom of the sedimentation tank. The mass of solids settled out in sedimentation is called raw sludge. In terms of efficiency of pollutant removal, typical primary treatment reduces BOD by approximately 35% and suspended solids by some 65%. Constituents not significantly affected

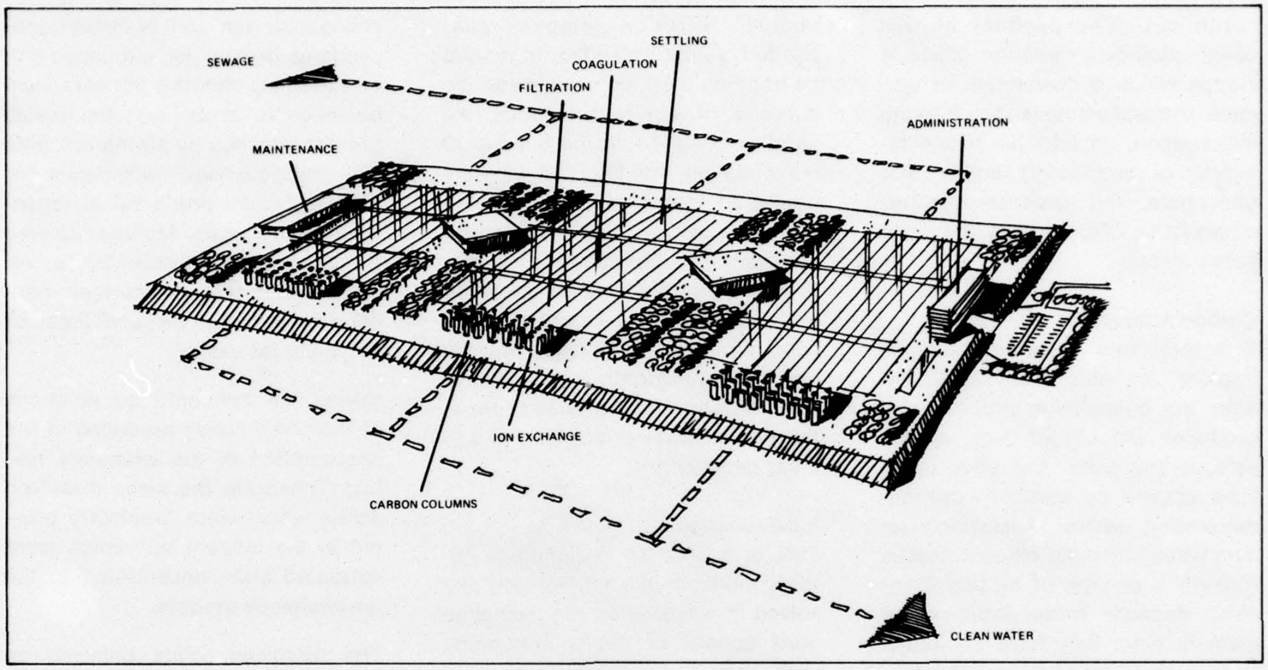


Carbon Adsorption Columns

include dissolved organics, heavy metals, nutrients and other dissolved solids.

To complete primary treatment, the effluent or liquid pumped from the sedimentation tank to outfall pipes undergoes chlorination. Chlorine gas is fed into the water to eliminate pathogenic bacteria, and after a thirty-minute retention period, the effluent is discharged into a receiving stream. By itself, primary treatment is completely inadequate for handling the sophisticated chemical pollutants common in modern wastewater. Nevertheless about 30% of all communities in the United States rely solely upon primary treatment to clean sewage.

While primary treatment works on wastewater physically, the second part of basic treatment, the activated sludge process, brings biological processes into play. After the wastewater leaves the sedimentation tanks of primary treatment, it enters an aeration basin where it is mixed with air, and sludge heavily loaded with beneficial bacteria. During the several hours that the mixture is held in the aeration basin, those bacteria break down many of the organic pollutants. The mixed liquor of wastewater and bacteria-laden sludge is then pumped to another sedimentation tank where solids settle out by gravity and are deposited on the bottom of the tank as sludge "activated" with bacteria. A portion of this sludge is recycled to the aeration tanks for mixing with incoming sewage and air to maintain the active biological com-



50 Acre Wastewater Renovation Plant

munity. When sedimentation is completed, the effluent can be chlorinated and discharged just as in primary treatment.

With the activated sludge process, the BOD and suspended solids removals increase to about 85% of the raw wastewater concentrations. That impressive advantage over primary treatment is certainly desirable, but activated sludge does have several limitations. First, it is vulnerable to toxic effects of some industrial waste components; the bacteria in the sludge can be killed outright and make an entire plant biologically inoperative. This difficulty is compounded by the fact that plant operators seldom know what the specific pollutants in incoming flows may be. And even if the composition were known, secondary treatment alone could not remove dissolved solids, heavy metals or nutrients like phosphorus and nitrogen. Despite these problems, secondary treatment is the goal of 90% of the municipalities in the United States. In the urban study areas reported on here, present wastewater treatment implementation plans call for the construction of sixteen such plants by 1976.

To deal effectively with the full range of wastewater pollutants, advanced treatment is required. The advanced systems commonly include four distinct operations: 1) coagulation-sedimentation; 2) carbon adsorption; 3) filtration; and 4) ion exchange.

Coagulation-Sedimentation

To remove virtually all remaining suspended solids and up to 90% of the phosphate, effluent from the secondary stage of treatment receives applications of alum or lime. These chemicals act as coagulants around which small and then larger particles of suspended matter cluster or "floc." By continuously mixing the wastewater mechanically, these solids increase in size until, in a sedimentation tank, they quickly

settle out. The product of this coagulation-sedimentation phase is sludge which is dewatered for ultimate disposal on the land or through incineration. In addition to the removal of suspended solids and phosphate, this process also reduces BOD, COD, viruses and some heavy metals.

Carbon Adsorption

This technique deals with the refractory organics remaining even after the coagulation process and produces effluent of high quality without any taste and odor problems caused by stubborn oxygen-demanding wastes. Adsorption occurs when incoming effluent passes through a column of carbon granules. Because these particles are many-faceted, they have enormous surface areas on which organic materials stick. To make this operation efficient and avoid clogging between granules, effluent can be pumped upwards through the column. The activated carbon particles themselves are cleaned by heat and reused. The carbon columns have an important ancillary use in denitrification, a process which converts nitrate forms of nitrogen (created from ammonia nitrogen in coagulation-sedimentation) into nitrogen gas which can pass off from the effluent directly into the atmosphere. This is accomplished by denitrifying bacteria maintained on the carbon granules, and fed methanol as a food source.

Filtration

More than a simple straining procedure, filtration removes suspended solids by adsorption and by trapping them on or between the particles of a porous medium like sand or coal. When the buildup of materials on the filtration medium begins to clog flow passages, the direction of the flow can be reversed. This backwash dislodges solid materials which are recycled to the coagulation basin for separation. When the resistance to flow has been sufficiently reduced, forward filtration may proceed. Here, the last residual of suspended solids is removed.

Ion Exchange

This is a process designed to remove the inorganic mineral salts dissolved in wastewater. Ion exchange units consist of resins containing ions, positively and negatively charged molecules, which can be replaced by similarly charged ions. Special acid resins will replace positive ions with hydrogen ions (H^+), and base resins will replace negative ions with hydroxyl ions (OH^-). These ions will then combine to form water (H_2O). Use of the above resins will reduce the dissolved mineral content instead of simply substituting one ion for another. When no more exchangeable ions are available, the resin becomes exhausted, and the contaminant appears in the effluent. At this point, forward flow is reversed as in filtration, and the resins are backwashed to remove collected contaminants. The resins themselves are then regenerated with a solution containing a new supply of the original exchangeable ion and treatment proceeds as before. Ion exchange can be extremely effective but care must be taken to insure that the resins are not attacked by strong oxidants like chlorine. New techniques for treating brines produced in regenerating the resin include reverse osmosis which concentrates removed salts and makes their handling for transit to disposal areas or recycling far easier.

Brines are concentrated solutions of dissolved solids produced in the regeneration of ion exchange resins. These are the same dissolved solids which were previously present in the influent but which were extracted and concentrated in the ion exchange process.

The dissolved solids removed on the resins come from many different sources. Some are present in the water initially; some are added as a result of municipal and industrial use; and some are added by wastewater treatment processes. The ocean is a compatible recipient for such high salt concentrations and is both a logical and convenient choice for disposal in this region, situated on the Atlantic seacoast.

If the treatment site where the brines originate is located some distance from the sea, it will be necessary to retain the brines in small lagoons where the liquid portion would evaporate, due either to an artificial heat addition or natural solar radiation. The residue salts would then be removed after evaporation and stored

prior to periodic transportation to the ocean for ultimate disposal at sea. Since these solids would redissolve in water, they must be kept dry during storage and transportation or they will be released to the environment in areas not compatible with such wastes.

Treatment Sequence

Properly designed and operated, wastewater treatment plants using all these processes in series can produce effluent of such high quality that it is suitable for drinking. For example, the city of Windhoek, South West Africa, troubled with inadequate water supplies caused by scant rainfall and brackish, foul-tasting surface water, has built a tertiary system which introduces its effluent directly into the municipal water supply. Each process in turn makes a particular contribution to wastewater renovation.

1. Primary treatment removes gross settleable material by screening and sedimentation;

2. Secondary treatment biologically removes many organic impurities;

3. Coagulation-sedimentation eliminates more discrete suspended solids, phosphates and some heavy metals;

4. Carbon adsorption removes refractory organics and is used as a support process for nitrogen removal;

5. Filtration eliminates still finer suspended solids;

6. Ion exchange reduces dissolved solids concentrations to acceptable levels; and

7. Chlorination kills bacteria potentially dangerous to public health.

8. All steps from 3 through 7 reduce virus contamination.

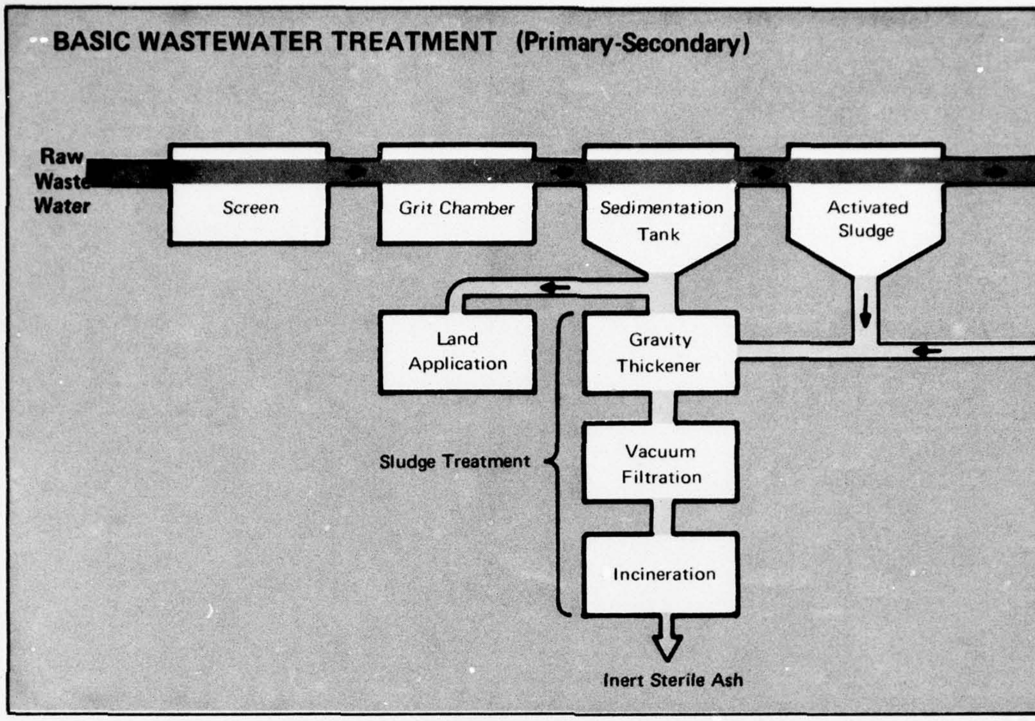
The primary-secondary-tertiary sequence is extremely effective but its component processes can be arranged differently. The physical-chemical (P-C) process as represented in several of the schemes also produces thoroughly clean water. In this kind of system, wastewater goes directly from partial primary treatment into coagulation-sedimentation, bypassing secondary treatment completely. A major advantage of that short-circuit is that the biological activity in secondary treatment which is so vulnerable to changes in environmental conditions can be avoided. In a physical-chemical system, there are no bacteria sensitive to toxic substances, changes in flows or temperature fluctuations. The result is a more predictably efficient treatment operation.

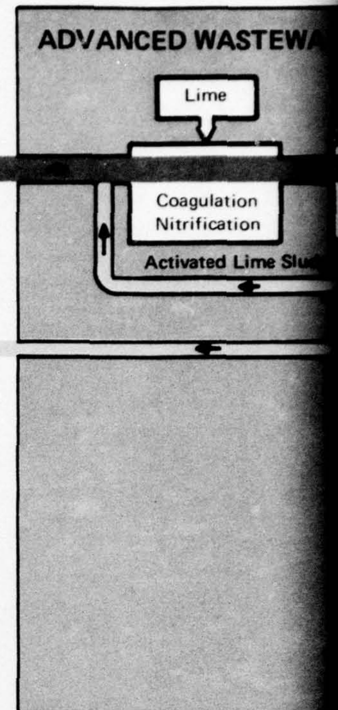
In a physical-chemical (P-C) system, coagulation-sedimentation removes virtually all suspended solids and their associated BOD as well as dissolved solids like the phosphates in detergents. This stage of treatment differs from its counterpart in a tertiary system in the amount of coagulant added and the quality of sludge removed. In a P-C operation, moreover, there is no recovery of lime from the sludge. Sludge disposal may be either by incinerator or land disposal.

The denitrification process in the P-C system is also different from its tertiary counterpart, but again the nitrogen treatment occurs in the carbon adsorption columns. Nitrogen (as ammonia) is removed by break-point chlorination. In this process nitrogen in the form of ammonia is converted to nitrogen gas for removal. Chlorine is introduced into the carbon columns as a gas where it reacts with the ammonia in the wastewater to form the nitrogen compound chloramine. Additional chlorine converts chloramines to molecular nitrogen, an insoluable gas which can pass off into the atmosphere from the cleansed effluent.

In physical-chemical treatment, the subsequent stages of filtration and ion exchange are performed precisely as in tertiary treatment.

Although P-C plants are not common, the technologies they employ are no longer experimental novelties. A plant at Lake Tahoe, using similar P-C processes on a secondary effluent, for example, has been operational since 1968 and treats a flow of 7.5 million gallons per day (MGD). A complete P-C plant to treat 60 million gallons per day is currently under design for the city of Niagara Falls, New York.

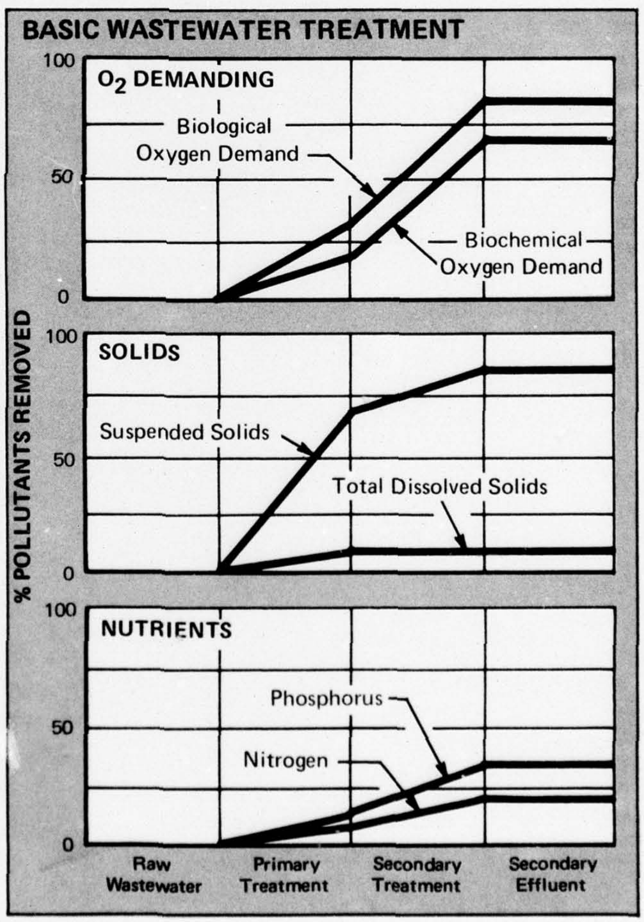


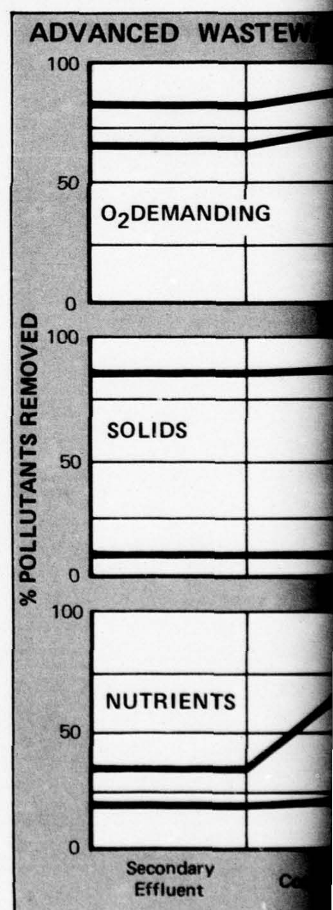


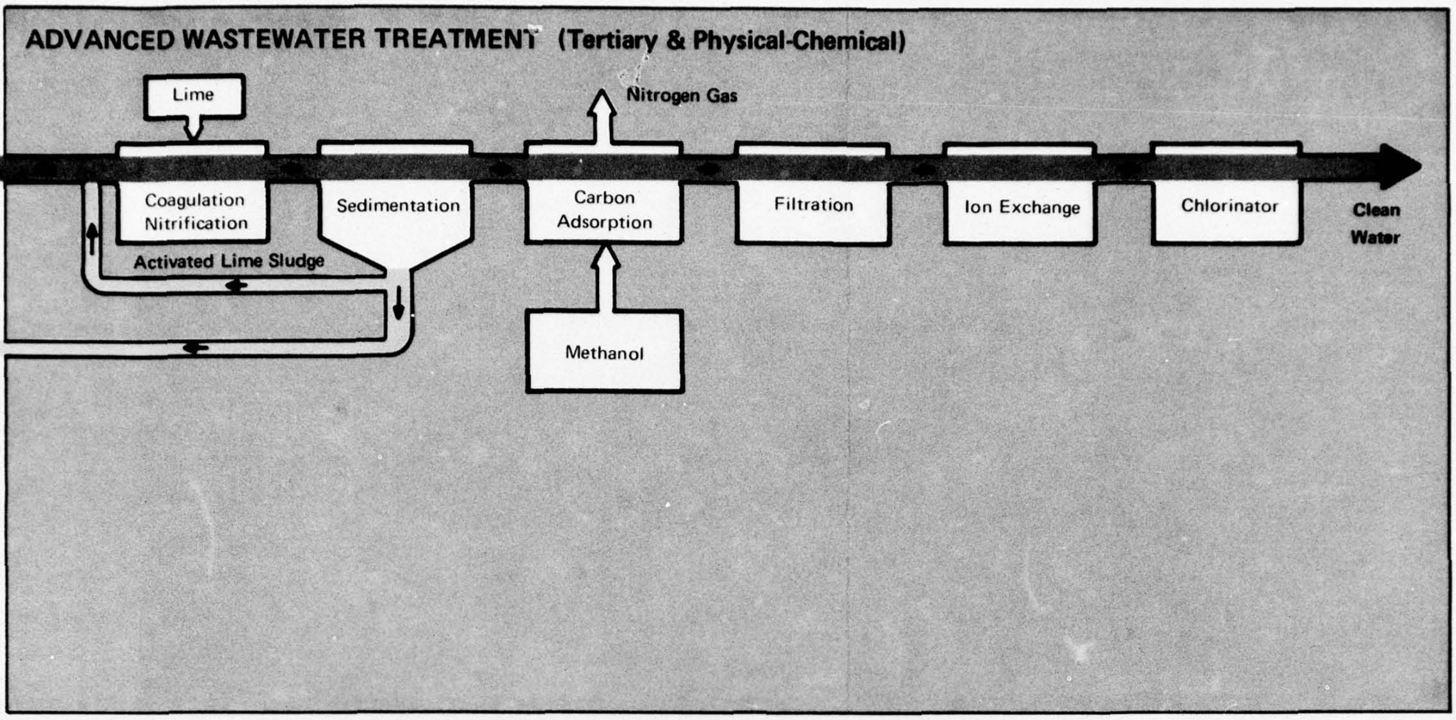
In primary treatment solids are screened and settled out of solution. Some of those solids will contain oxygen demanding wastes. Secondary treatment will result in the bacterial breakdown of the organic matter containing oxygen demanding wastes. These wastes will be removed as the decomposed solid waste and bacterial sludge is settled.

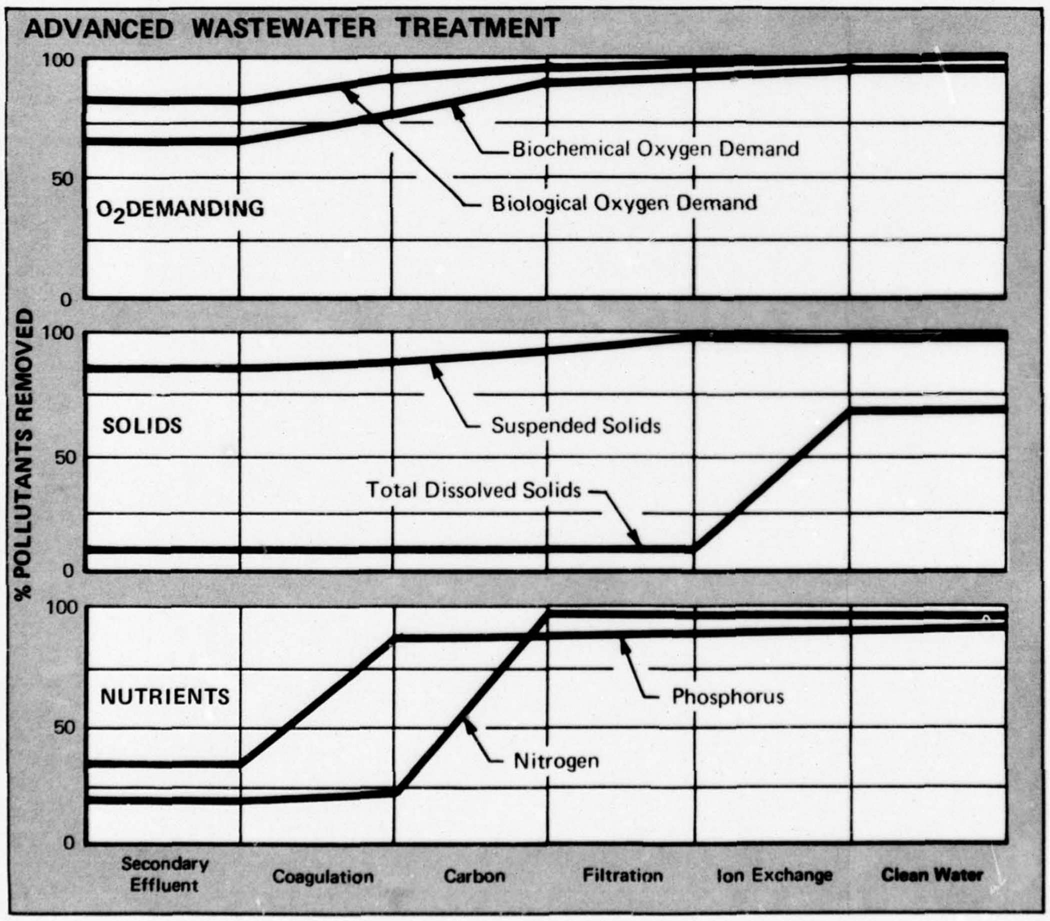
In primary and secondary treatment, there are sedimentation tanks where the wastewater is allowed to rest for specific time intervals. In these tanks the suspended solids will settle and be removed as sludge. Very little of the stubborn dissolved solids can be removed in this fashion.

Although nutrients are found in the food chain of aquatic organisms and plants, those nutrients associated with cell growth do not represent a significant reduction in concentration through primary or secondary treatment. The organic matter, now cells, is removed by settling.









Because the secondary effluent still contains suspended solids, those oxygen demanding wastes found in the solids remain to be removed. The solids may be coagulated and settled in the coagulation-sedimentation system. Those still in solution may adhere to the filter media in filtration or in carbon adsorption.

In coagulation-sedimentation, lime causes the suspended solids to coagulate into large settleable masses. Those solids still remaining will adhere to the filter media in filtration and carbon adsorption. Carbon adsorption removes those dissolved organics that create taste and odor problems; ion exchange reduces the dissolved inorganics.

In coagulation-sedimentation, lime makes the phosphorus insoluble and settleable. In Physical-Chemical chlorine is added to the carbon columns to convert the nitrogen to an insoluble gas. In Tertiary the nitrogen is biologically treated in the coagulation-sedimentation units so that it may be converted to an insoluble gas in the carbon columns.

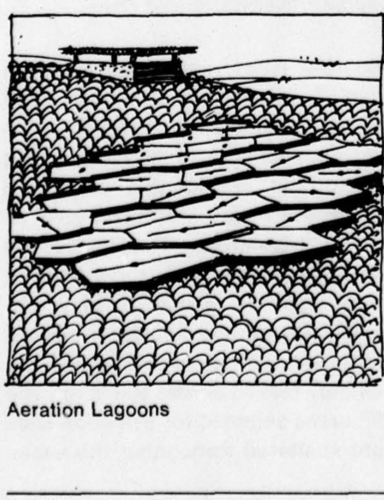
Land Oriented Processes

Water-oriented primary, secondary and tertiary/physical-chemical processes are not the only approaches to wastewater renovation. In addition to the treatments that discharge effluents into water, there are techniques which substitute the land as a treatment medium. To achieve basic treatment, for example, it is possible to use aerated lagoons interchangeably with the activated sludge process.

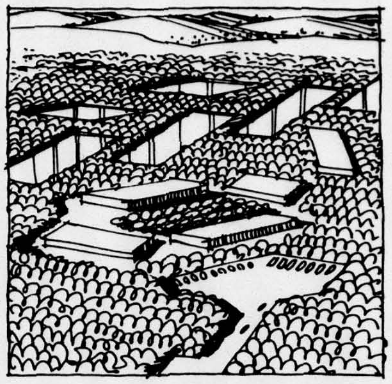
Treatment Lagoons

Lagoons are specially constructed ponds usually about ten feet deep in which algae, oxygen, and sunlight interact to oxidize organic wastes. Properly designed and operated, these lagoon systems can produce effluent water of secondary level quality.

In a land-disposal system, raw wastewater is first screened and then pumped into the lagoon where rotating units mechanically create a turbulence which insures a distribution of air. This promotes decomposition by those bacteria which require oxygen (aerobic bacteria). Without induced turbulence, those solids which will not stay in suspension settle to the bottom and are decomposed by bacteria which do not require oxygen (anaerobic bacteria).



Aeration Lagoons

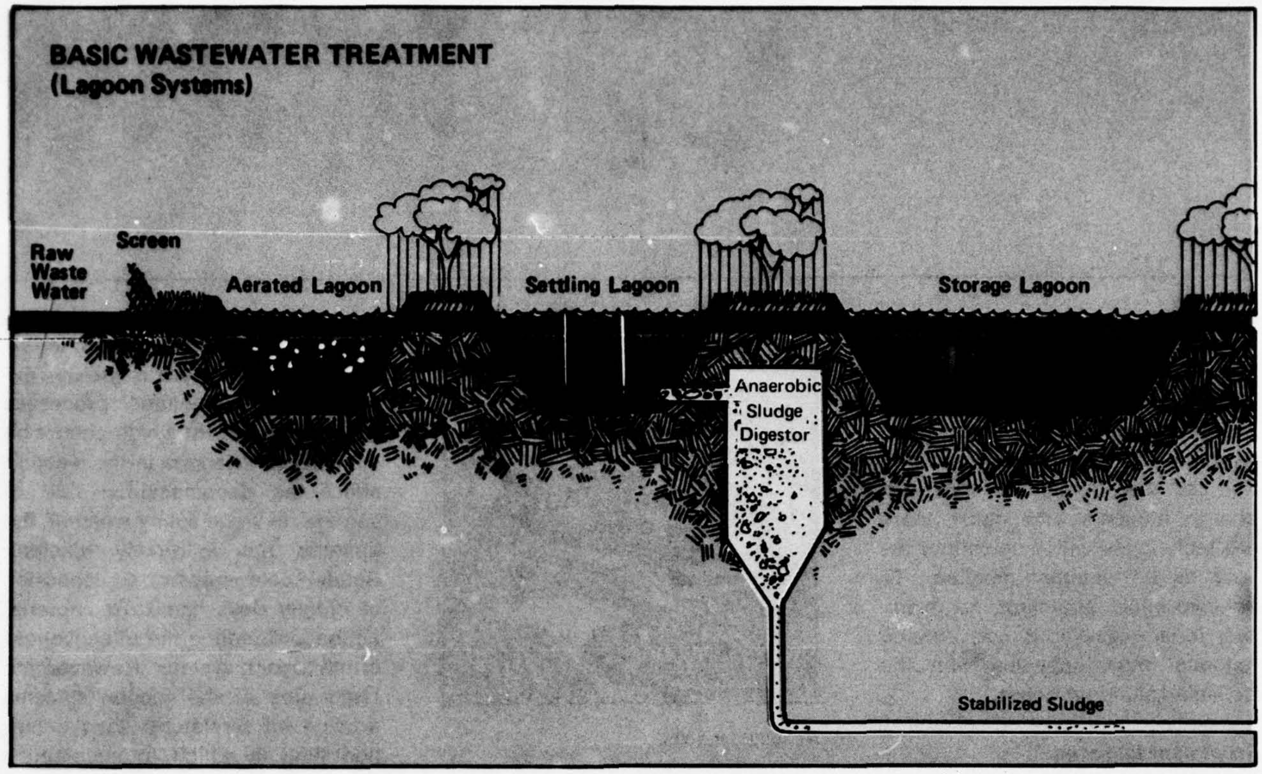


Settling Lagoons

After treatment in an aerated lagoon, the wastewater is pumped to a settling lagoon. Here decomposed solids are allowed to settle to the bottom and concentrate into a sludge. From the settling lagoon, effluent can go either to a storage lagoon for containment or to outlet lagoons, where more solids are deposited and chlorination eliminates pathogenic bacteria.

Since this method of wastewater treatment relies upon biological processes, it is sensitive to the same types of environmental changes as the activated sludge process. In this case, however, there is greater exposure of the treatment processes to the environment which cannot be controlled. Changes in the weather affect the decomposition rate of sewage; in warm sunny weather, the bacteria are extremely efficient. Sudden cold snaps or a succession of cloudy days can slow bacterial action and reduce the effectiveness of the lagoon system. However, the large size of the lagoon systems provide for a relatively long detention time in which to accomplish treatment, approximately three days. In addition, the size of the system would enable toxic spills to be isolated in one of the lagoon cells with the continuing wastewater diverted around it into adjacent lagoons which would continue to function. Moreover, bacteria are vulnerable to toxic wastes regularly or accidentally added to wastewater, and cannot remove complex inorganic or synthetic chemical compounds.

Storage Lagoons

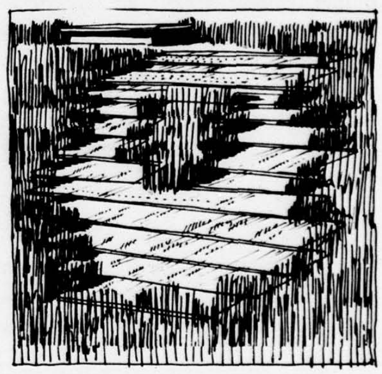


Just as there are advanced water-oriented processes which will renovate wastewater, so there are land techniques which accomplish the same purposes. After chlorine disinfection, the effluent from a lagoon system can be applied directly to the land and further purified by the physical, biological, and chemical action of plants and soils. The Santee Recreation Project in Santee, California, for example, uses a series of lagoons and a large percolation area to produce an effluent used to create a pond clean enough for public swimming.

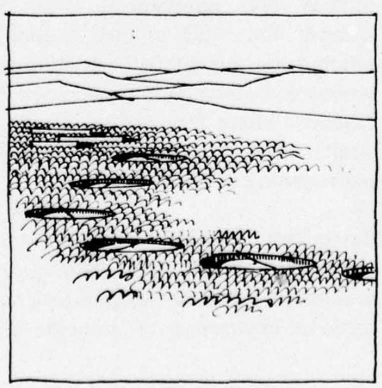
The land technique is not a new one; land disposal of wastewater has been practiced for many years. In this study, however, because used water is considered a resource too valuable to throw away, the emphasis has shifted from "disposal" to land-based renovation and recapture of the water for reuse. Consequently, in the schemes which use land techniques, both the rates of wastewater application and subsequent collection of cleaned water are carefully controlled and monitored.

Spray Irrigation

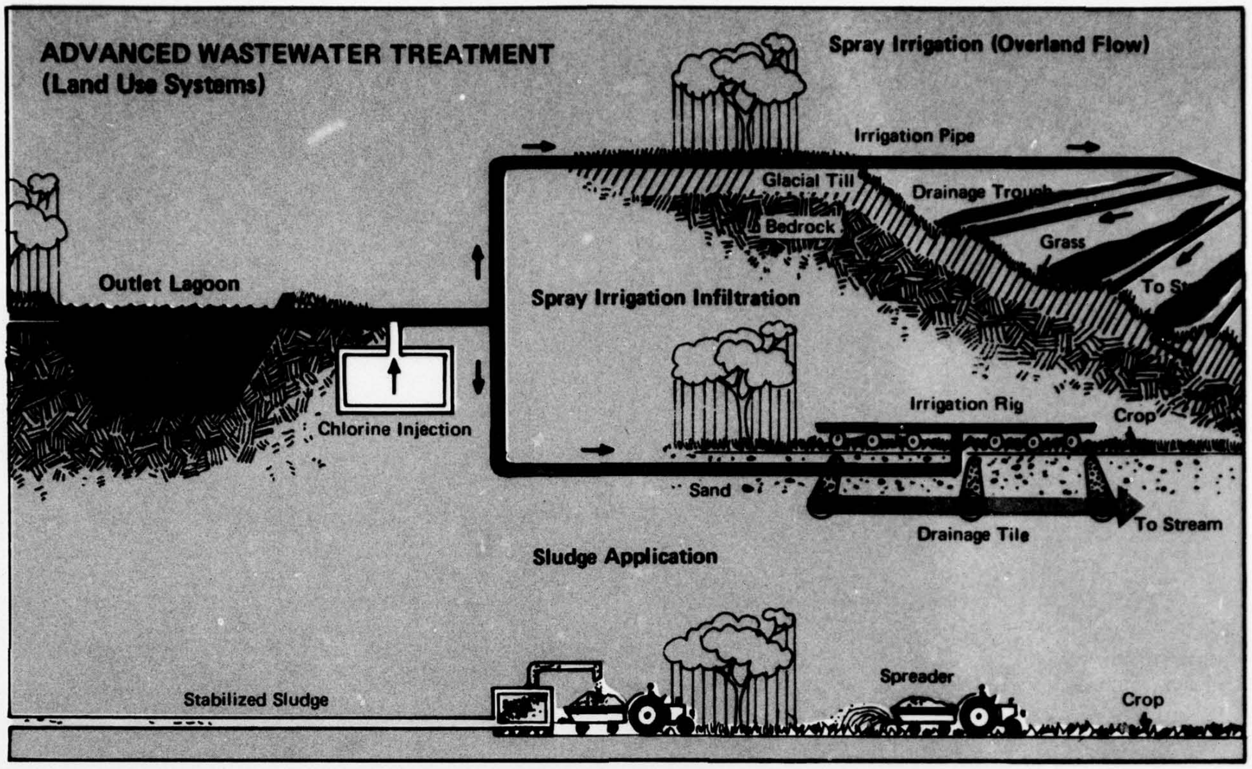
When wastewater is to be cleaned by the land, three separate but interrelated issues must be taken into consideration; the nature of the land, the method of application, and alternatives for collection of the renovated water. In the Merrimack Basin, receiving soils are of two general types, sand and till. The sand is loose and permeable. The deposits selected for irrigation sites are commonly more than twenty feet thick, and are located along the mainstem of the Merrimack and its major tributaries. The till is not very permeable and is generally a tight unsorted mixture of clay, silt, sand, gravel, and boulders jumbled together and deposited by glaciers as they moved across the land. The till areas selected for irrigation sites are scattered throughout the basin,



Spray Irrigation Overland Flow

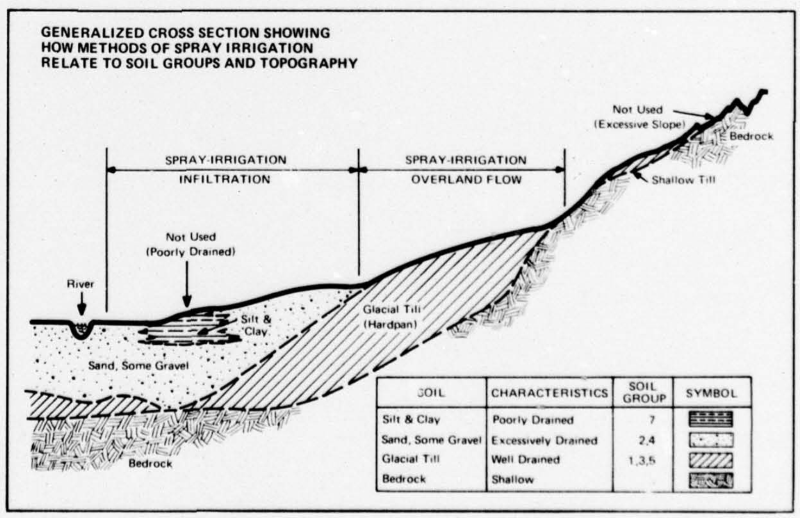


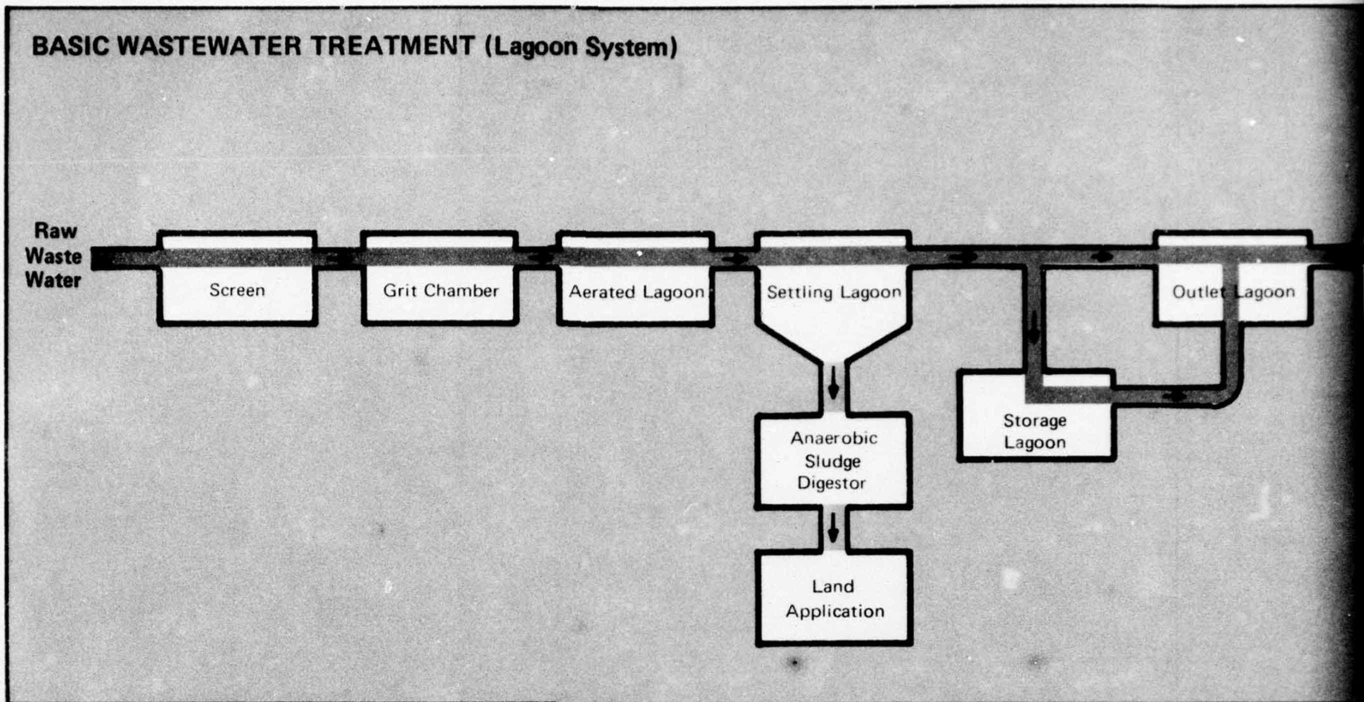
Spray Irrigation Infiltration



are shallow to bedrock, and are usually less than twenty feet thick. Although there are other techniques possible, spray irrigation has been the method of effluent application suggested for the Merrimack. Other methods like perforated pipe and furrow channels have been considered and rejected because of operational problems or because they don't conform well to the land contours or farming techniques of New England.

In an irrigation scheme, wastewater having received basic treatment in the lagoon system is pumped through standard irrigation equipment—pipes, risers and nozzles — onto cropland or forest cover for twenty-six weeks of the year. Depending on the type of soil the irrigant falls on, it will either infiltrate downward, as in sand, or flow downslope in a thin sheet at or just under the land surface when the site is in glacial till. In either case, whether the effluent moves by infiltration or overland flow, the vegetative cover and the soil itself improves the quality of the wastewater significantly, making it suitable for a wide range of new uses. When overland flow is used the rate of wastewater application must be slower than in infiltration since renovation only takes place at the surface. The rates of application are one inch per acre of land per week for overland flow (till soils) and two and one half inches per acre per week for infiltration (sand). In both cases the wastewater would be sprayed in two applications per week at a quarter of an inch per hour or less.

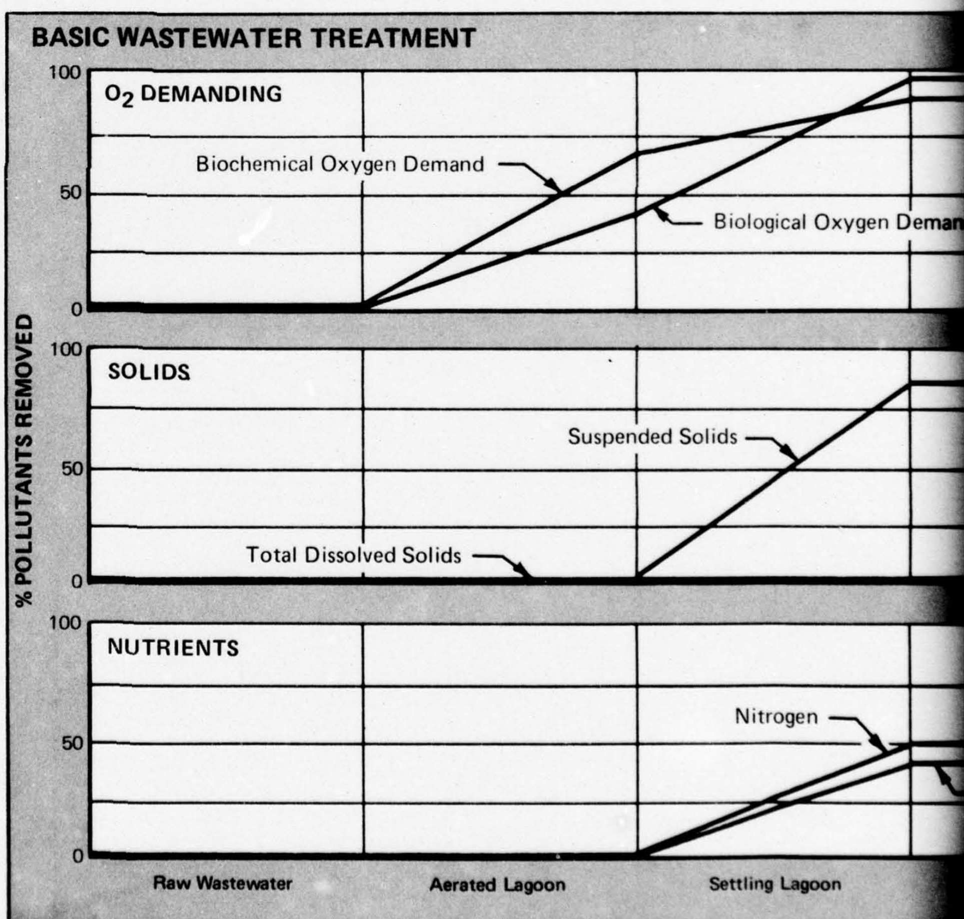


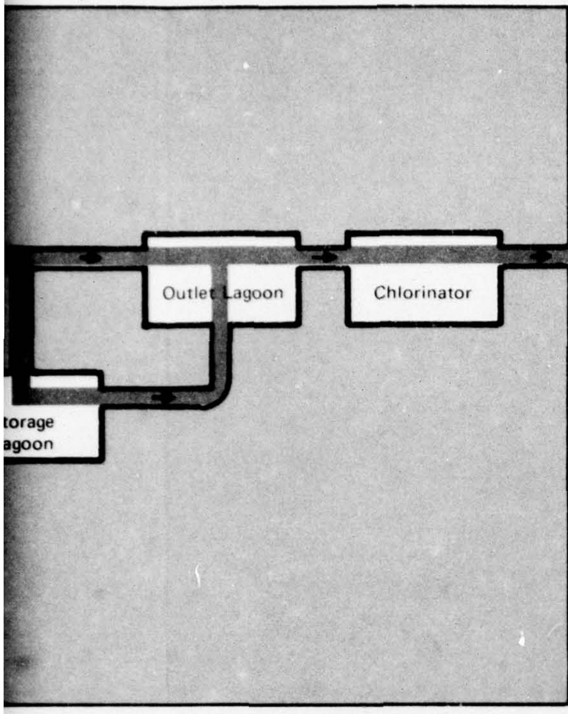


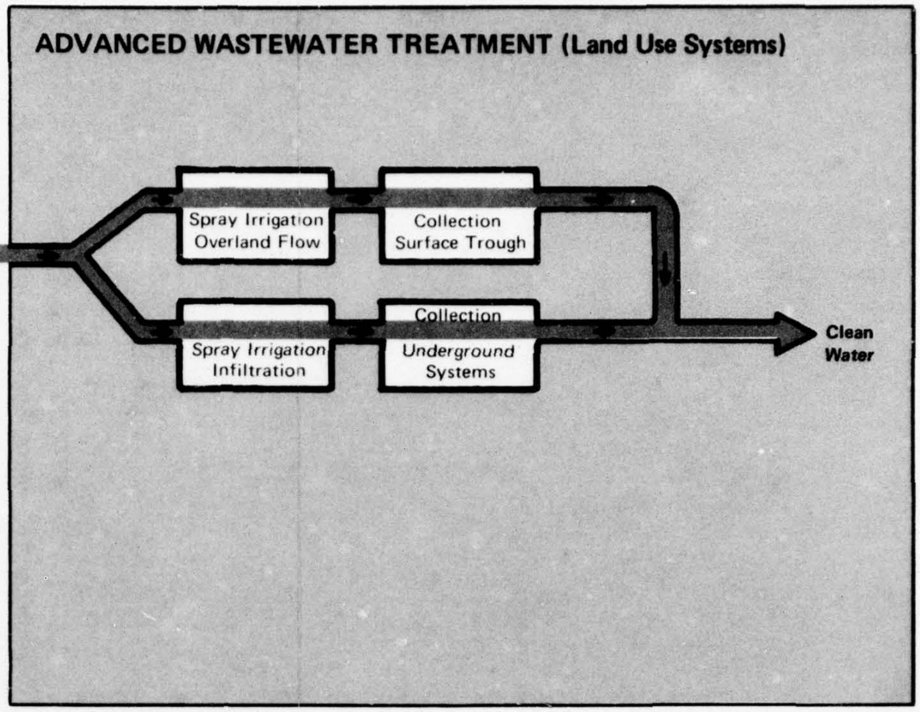
Because fish and other aquatic life must compete with oxygen demanding wastes for enough oxygen to sustain life, these wastes must be removed. Removal may *be done biologically* by aerobic bacteria that thrive in the aerated lagoons. Solids containing the decomposed wastes are then settled to the bottom of the settling lagoons.

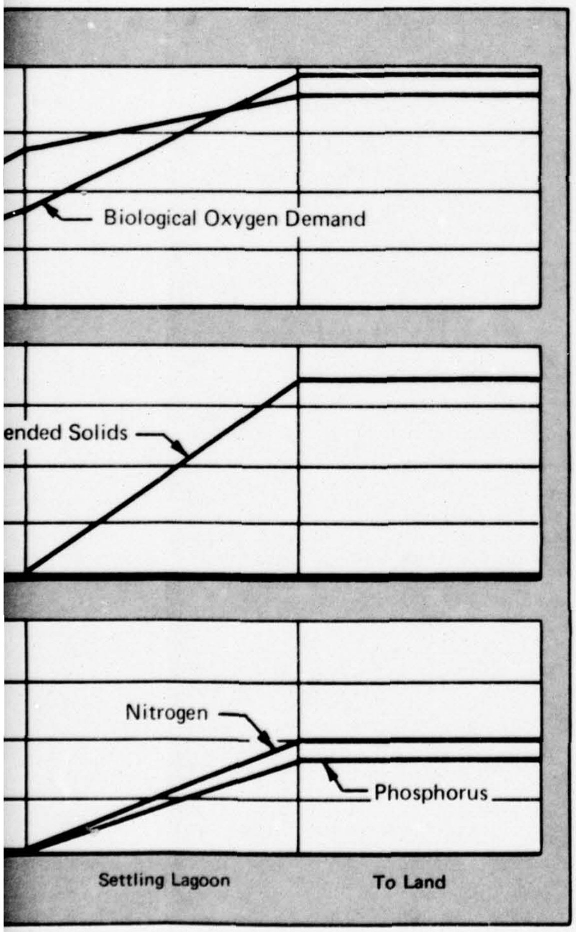
In the settling lagoon the wastewater is at rest and the suspended solids are allowed to settle and concentrate into a sludge. Total dissolved solids, substances not decomposed by bacteria, are inorganic in character and will not settle out.

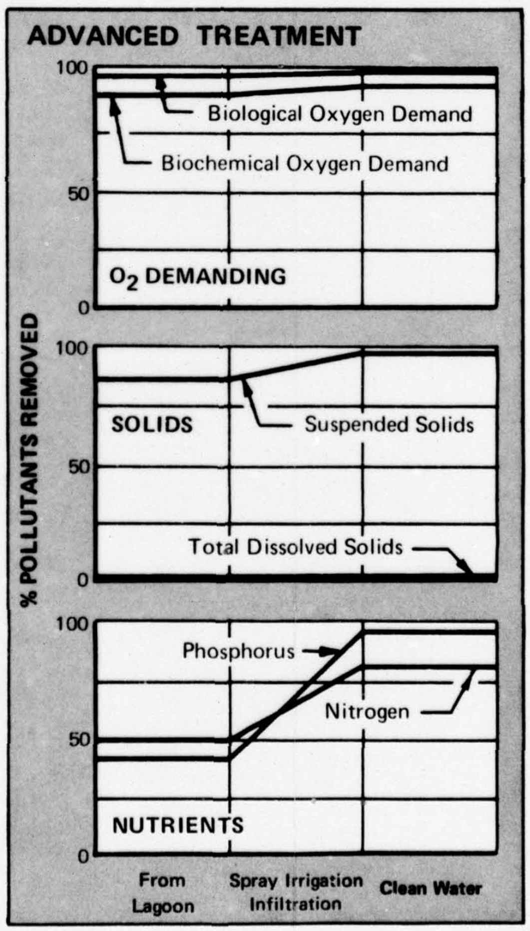
Nutrients are found in the food chain of aquatic organisms for support and stimulation of their growth. They also exist in a dissolved state in the wastewater. Those nutrients associated with the decomposed biological waste from the aerated lagoon will settle with that waste in the settling lagoon.











As wastewater flows through soil and vegetative cover in spray-irrigation, some of the solids will be filtered out of solution. Those oxygen demanding wastes that are found in the filterable material will be removed.

Various sized particles of sand, soil, and gravel, as well as vegetative cover, will act as filter media as spray-irrigated wastewater flows through it. Most of the remaining suspended solids will be filtered out. Dissolved solids will pass through the filter media along with the treated wastewater.

Nutrients are substances that are essential for plant growth. As wastewater flows through vegetative cover during spray-irrigation, the plants will remove the nutrients for fertilization of the plants' growth.

Irrigation is compatible with a variety of different land uses. It can take place on cropland in hay, corn, or truck crops or even on forest cover, with plants and trees utilizing the nutrients in the effluent for faster growth. Other kinds of cleared land can also profit from irrigation with wastewater-pastures, golf courses, and possibly even ski slopes.

Soil conditions also determine the method of collection for water cleaned by the land. On sand, there are two possible alternatives. Where the water table is less than six feet below the surface, an underground drainage system of tiles can be installed to recapture water which has filtered through the ground. Where the water table is below six feet, it might be more practical to install wells at given intervals and simply pump ground water, including the renovated water to the surface. On till soils where overland flow would occur, water can be collected on the surface either in natural troughs, or constructed channels. Whatever the method of collection, water cleansed by the land can be continuously monitored for quality and directed to desired uses.

The amount of nitrogen in the wastewater applied to the land is critical to the success of this kind of wastewater management. Since heavy concentrations of nitrogen are undesirable, loading or application rates have to be carefully controlled to be consistent with the ability of plants, bacteria, and soil particles to use or hold nitrogen. Figuring the amount of nitrogen in the wastewater to be fifteen to twenty parts per million (ppm) after basic treatment, an application rate of two and one-half inches of water per week would make about two hundred twenty to two hundred ninety pounds of nitrogen per acre available to vegetation over a twenty-six week period.

Plants and the soil utilize and store a portion of that amount. Ammonia forms will be denitrified by anaerobic bacteria in the soil or adsorbed to individual soil particles. Nitrates can be used as an oxygen source by bacteria to decompose organic material. Varying by the capacity of the site to use applied nitrogen, some portion may pass beyond the root zone and continue to move through the soils below. There is conflicting evidence about the amount of nitrate nitrogen which eventually might reach groundwater. However, suffice it to say that sound wastewater management should aim at preventing or minimizing nitrate addition to the groundwater. A thorough investigation of potential irrigation sites must be carried out in order to design underground drainage systems capable of complete groundwater management.

Not only is it possible to treat wastewater with water-oriented and land-oriented techniques, it is also possible to use individual processes from either category in combination. For example, where soils suitable for land renovation are abundant but a harsh winter climate prevents year-round spray irrigation, complete tertiary treatment can be performed in urban treatment facilities during the cold months and on the land during warm weather. Combination schemes like this allow for great flexibility in the design of wastewater treatment systems. Schemes No. 5, No. 6, and No. 7 in Chapter 4 show how the best features of different chemical and biological processes can be tailored to conform to the requirements of particular regions.

SPECIAL CASES

The kinds of water and land processes just described are usually applied to domestic sewage combined with flows of industrial wastewater and stormwater. However, some industrial process waters contain pollutants which could impair or destroy the operation of treatment plants if they were discharged directly into municipal systems. Other wastes contain process materials too valuable to discard. In these

cases, industries attempt to eliminate or must recover pollutants in-plant before process water is allowed to enter the larger environment.

Increasingly, industry recognizes that cleaning water used in manufacturing is a legitimate cost of doing business and that the responsibility for environmental quality does not leave the plant with the process water. To meet that responsibility, manufacturers have several options. They can provide total in-plant wastewater treatment which produces effluent as clean or cleaner than water quality standards require. They can completely recycle wastewater and its pollutant components and produce no effluent at all. More often, though, industries will either pre-treat their wastewater and produce an effluent acceptable for further treatment in municipal systems or alter production processes themselves to use non-polluting materials less damaging to water or more easily removed.

In the Merrimack Basin, major industries can eliminate a good portion of the gross pollution now discharged directly into the river by making use of one or more of these approaches. The first step toward that goal is to identify the pollutants associated with each type of industry and then apply the treatment techniques appropriate for their removal.

Pulp and Paper

Accounting for about two-thirds of the total industrial wastewater flow in the basin, pulp and paper manufacturers in the Fitchburg-Leominster and Lowell-Lawrence-Haverhill areas produce effluents containing suspended solids like bark and silt, soluble solids including both organics (sugars and carbohydrates) and inorganics (salts), and dyes. High BOD levels could overload the ability of a municipal wastewater treatment plant to handle organic materials and some of the fibers contained in the process wastewater could clog machinery in the municipal plant.

For most paper operations, therefore, pre-treatment is a virtual necessity. Screening will catch large solids and grit will settle. Small bubbles of air can be introduced into the wastewater and as they rise to the surface, carry with them fine wood fibers which are skimmed off and recycled into the paper-making process. Finally, before being discharged for secondary treatment, the temperature of paper waste must be reduced and pH levels indicating acidity corrected. Whether or not basic treatment continues at the paper plant or in a municipal facility, tertiary treatment will be necessary to remove all traces of color and reduce BOD to minimum levels. Recycling in-plant is an attractive alternative because valuable by-products like turpentine, yeast, and alcohols can be recovered profitably.

Textiles

Textile producers in the Merrimack Basin are concentrated in Manchester, New Hampshire, and in the Lowell-Lawrence-Haverhill area. They produce two kinds of pollution loads: the natural fiber itself and the chemicals used to process it. Raw wool contains large amounts of soil, excrement, blood, oily matter, and vegetable material. Before it can be used to produce cloth it must be cleaned, first by washing in fresh water and then by scrubbing with soap and detergents. Chemical pollutants include sizing, anti-static treatments, spinning lubricants, dyes, and finishes like starch. Cotton wastes have high BOD and substantial amounts of those refractory or stubborn organics unaffected by basic (secondary) treatment.

The treatment techniques for both kinds of fiber are very similar.

1) Grease removal by the addition of acid and recovery for refinement to lanolin (wool only);

2) Screening for removal of suspended fibers;

3. Air floatation or bubbling to carry fine fibers to the surface for skimming;

4) Chemical coagulation to remove solids; and,

5) Biological treatment to raise the percentages of BOD removal above 90 percent

Dyes may require tertiary treatment to remove their intense color from wastewater.

Tanning

Major tanneries in the Merrimack Basin are located in the Nashua, Manchester, and Concord areas. The wastes produced by leather manufacturers are heavily organic, containing suspended particles of flesh, hair, dissolved proteins, fats, and soaps. Inorganics are also present. For example, hides are shipped to tanneries preserved in salt which must be washed away before lime baths can loosen remaining hair and pickling in sulfuric acid can proceed. Also, chromium salts are used in the tanning process to produce leather.

A variety of treatment techniques including the blending of wastewater flows from different portions of the tanning process can improve water quality significantly before discharge. Coagulation will settle out much of the suspended solids material. pH can be corrected by the addition of carbon dioxide which neutralizes lime. In-plant biological treatment can be used but is seldom performed because of its high cost.

There are possibilities for recycling and reuse of waste products in the tanning industry. Chrome tanning solutions, for example, could be collected and recirculated. Some tanners can profitably render the fleshings removed from incoming hides to recover grease used in the manufacture of soap.

Plastics

The production of polymers account for the largest portion of all plastics production in the Merrimack Basin. Most producers are located in the Fitchburg-Leominster area with a few in Manchester, New Hampshire. Most of the wastewater flow results from an operation where the polymer is water-washed. Beyond cleaning operations performed on the product itself, water used to clean and rinse contaminated vessels or floors can become seriously polluted. Generally, wastewaters contain settleable and colloidal solids, some foam or odor producing materials, and high concentrations of BOD-exerting materials like dispersants and emulsifiers.

To remove these pollutants in-plant, the treatment sequence may include screening and grit removal, neutralization of pH, coagulation and activated sludge. Tertiary treatments performed include filtration, carbon adsorption and ion exchange.

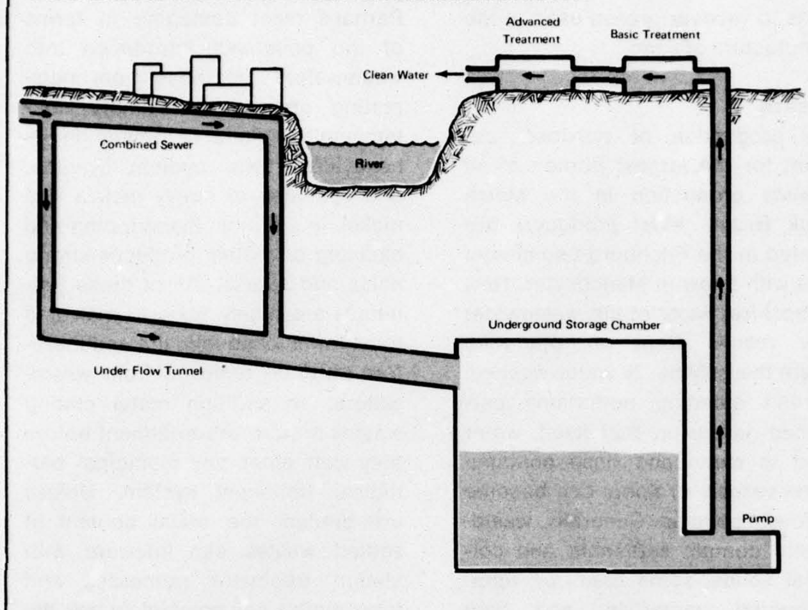
Some substitutions for additives which significantly reduce water quality and which are difficult to remove may be possible, but so far no substitution for the principal raw materials, monomers, is practical. More promising are the recovery and recycling of process materials.

Metal Plating

Perhaps most damaging in terms of the pollutants introduced into wastewaters are those from metal plating operations. Primary contaminants include chromium in its hexavalent form, sodium cyanide, and cyanides of heavy metals like nickel. In addition, the stripping and cleaning of metals produces strong acids and alkalis. All of these pollutants are highly toxic to man and most forms of aquatic life and therefore must be removed from wastewaters. In addition metal plating wastes require pre-treatment before they can enter any municipal biological treatment system. Unless well-diluted, the metal content of settled wastes can interfere with sludge treatment processes and toxic metals can completely halt the biological reactions in the activated sludge process.

Cyanide treatment can be accomplished in several ways one of which is through ion exchange. However, the most common technique is to raise the pH to about eleven and then destroy the pollutant cyanide by oxidation with chlorine gas. The treatment of chromium can be accomplished by reducing it from a toxic hexavalent form to a trivalent form and then precipitating it out with a lime slurry. In some systems, recycling may be possible. For example, rinse waters may be evaporated; the concentrate containing cyanides returned to the plating

UNDERGROUND STORAGE CHAMBER FOR STORMWATER RUNOFF



bath, and the distillate reused as rinse water. Other possibilities for recycling lie in concentrating and stockpiling the sludges produced by treatment, and later mining them for metals.

Stormwater

The other class of wastewater which requires special attention in the designs for a regional treatment system is stormwater. The treatment of stormwater is essential if maximum feasible purity in the Merrimack is to be attained and then maintained. One approach to the problem would be to construct separate storm and sanitary sewer systems in cities and towns which now have combined collection systems, but even if the public could accept the disruption of opening every street and road in town, the cost in dollars would be astronomical. Another strategy — to construct treatment facilities large enough to handle regular municipal wastewater flows plus stormflows — would also require tremendous capital outlays to increase the capacity of treatment plants commensurate with increased stormwater flows.

The schemes presented in this report use still a third approach. The idea is to build basins either on the surface or below it into which storm flows combined with sewage can be channelled from existing collection lines. Designed to hold the volume of flow produced by the five-year/six-hour storm, these retention basins would store wastewater temporarily. During the retention period, aeration and sedimentation would take place. Having received the equivalent of primary treatment, the stormwater sewage mixture would then be pumped out of the retention basins over a period of fifteen days or less into the municipal treatment facility for complete renovation.

This method of handling the stormwater sewage mixture is particularly attractive because of its flexibility. For example, during periods when parts of a treatment plant must be shut down to allow for maintenance, the storage system could temporarily store incoming sewage and *industrial* wastes. Moreover, in emergencies, the reserve capacity of surface or underground basins can provide back-up space for wastes which would otherwise go directly into receiving waters.

PRODUCTS

For the municipal systems handling domestic sewage, pre-treated industrial wastes and stormwater, the principal products of wastewater are two: renovated water of extremely high quality and solid materials. The former is suitable for the range of uses suggested in Chapter 1 and need only be directed to recreational areas, drinking supplies, etc. Solids or sludges removed in the course of wastewater

treatment, must still undergo further treatment before they too can be considered "treated."

Sludge Disposal

Primary sludges from sedimentation units are about 98.5 percent water and sludges produced by secondary and tertiary treatment are even higher in water content. The sludges must be thickened before dewatering can be accomplished. The thickening process is accomplished through mechanical stirring which produces clumps of more readily settleable sludge. The formation of these flocs or clumps is generally induced by the addition of lime or polymer coagulants. Even at best, however, water is very difficult to separate from its associated solids and it is not practical to thicken sludges to a solids concentration of more than 10 percent.

After thickening, the sludge undergoes a dewatering process known as vacuum filtration. In this operation, sludge is drawn by suction against a revolving drum that is partially submerged in a sludge tank. The drum is covered with a porous filter medium such as cloth, steel mesh, or tightly wound coil springs. As it rotates, most of the solids in the sludge slurry stick to the surface of the drum while most of the liquid passes through the filter medium. As the newly formed "filter cake" or residue emerges from the tank, it is air dried and then scraped with a knife edge onto a conveyer belt. As the filter drum continues to turn it is washed with water spray to prevent clogging before it is immersed once again in the slurry tank.

With dewatering, the solids to water ratio in the sludge gets raised to between 25 percent and 40 percent. At this stage, there are two alternative approaches to handling the sludge. It can be incinerated or distributed on the land improving soil structure and releasing nutrients to the vegetation.

In a physical-chemical treatment system, the solids in the wastewater which have been separated from the liquid resemble the traditional raw and digested sludge of conventional treatment in some ways yet is quite different in other ways. For example, the density of a physical-chemical sludge is less than that of a conventional treatment unit. Due to the addition of aluminum or iron salts, the physical-chemical sludge is much higher in metal content than conventional sludges. Nevertheless, the solids in a physical-chemical sludge are similar to that from a conventional system in one fundamental area, specifically, that the solids removed remain as unstabilized organic matter. This provides a potential for odor problems.

The material in sludges from tertiary facilities have received sufficient treatment to remove the unstabilized organic material to such an extent that the threat of odor no longer exists in this case.

Two fundamental approaches to the stabilization of the physical-chemical sludge are available. First, there is the option of incineration of dewatered sludge with the sterile residue disposed of in a landfill operation. A second alternative possible deals with the digestion of sludge for stabilization of organic matter prior to dewatering and land application as a soil conditioner-fertilizer.

Incineration

Incineration which concentrates the sludge down to an inert ash is carried out in two steps. First, sludge is dried; i.e., heated to the boiling point with the water contained in the solids driven off as water vapor. Then, combustion takes place in the

presence of fuel, high temperature, and air turbulence. Incineration products include an inert sterile ash and stack gases such as nitrogen, oxygen, water vapor, and carbon dioxide. With modern equipment and good management, these gases should not pose an air pollution problem. However, a monitoring program will be required wherever incineration is implemented in order to guide good operating practices.

Land Disposal

The other alternative for sludge handling is land application. Sludge is a source of plant nutrients as well as being a useful soil conditioner. Once dewatered, it can easily be spread mechanically on cropland, pasture, golf courses, and lawns. More manageable than liquid sludge, digested dried sludge can be applied at a rate of forty to fifty tons per acre every four years. At this rate, a total of 1,600 to 1,700 acres could handle all the sludge produced in the basin over a year's time.

Although land application is not a new technique by any means, there are some precautions to be taken. When used on soils which produce vegetables or fruits eaten raw, it should be applied the previous fall, plowed under, and planted to a cover crop. On haylands, it may be spread in the spring or after hav harvest in early summer to avoid rejection of the grass by cattle.

In terms of economics, the use of dried sludge rather than the liquid form seems to be consistent with the small fields of New England farms.

Hauling and spreading by truck within a twenty-five mile radius of the treatment facility is one of the methods contemplated in this study for sludge disposal.

Once the nature and magnitude of the pollution problem in the Merrimack had been determined and a full range of remedial technologies surveyed, the Feasibility Study team began to interrelate them. First the existing EPA-State implementation program was examined and those treatment facilities for which definitive plans were in existence were noted. There are 10 such plants in the implementation program scheduled for construction or for major upgrading. In addition there are four smaller secondary treatment plants, in the implementation program, located at Hooksett, N.H., Chelmsford (2) Mass., and Billerica, Mass. These plants will operate as now designed within any of the seven schemes and are not further considered in these plans.

The next step was the development of alternative wastewater treatment strategies responsive to the water quality objectives set forth for this study. All seven schemes were based on the projected loadings for the year 1990 which in turn stem from the accepted population and economic projections. These projections and the wastewater volumes associated with them are shown in the Design Data table.

In the remainder of this chapter each alternative solution is presented. Beginning with the EPA-State implementation program and continuing with the seven alternative schemes each is described, its costs are tabulated, specific considerations discussed and their impacts delineated.

All wastewater schemes, the EPA-State Implementation program and the seven illustrative schemes will have significant impacts on the river and its environs. Some of these impacts will occur directly due to wastewater management while others need additional actions or investments. The impact statements shown here and later in this report denote the type and magnitude of the impact. This is important as many schemes produce similar impacts but of different magnitude. Some of the impacts common to all programs are listed here.

DESIGN DATA 1990 CONDITIONS

SUBREGION	POPULATION (THOUSANDS)		WASTEWATER FLOW (MGD)		
	TOTAL	SERVED	M & I*	STORM	TOTAL
Winnipesaukee River	34.1	30.7	12	22	34
Concord	69.3	55.7	14	17	31
Manchester	168.7	148.0	34	18	52
Nashua	132.8	118.5	29	21	50
Fitchburg-Leominster	108.5	98.3	40	24	64
Lowell-Lawrence-Haverhill	454.4	360.0	96	49	145

*Includes considerable amounts of groundwater infiltration into sewer systems.

- *Removal of municipal and industrial waste from the river will allow the establishment of additional species of plants and animals in all segments of the river and the estuary.*
- *The diversity of benthic organisms in the Merrimack and Nashua Rivers will be considerably increased.*
- *The number of waterfowl and shore birds frequenting the estuary during their migration will increase as food organisms respond to reduced pollution.*
- *Available fishery resources in the Merrimack Basin will increase substantially.*
- *There will be major degradation of the terrestrial ecology at the treatment plant sites.*
- *The bacterial pollution of the rivers of the Merrimack Basin will be considerably lessened.*
- *The potential of diseases stemming from recreational activities associated with the river will be greately reduced.*
- *Crops irrigated with water from the Merrimack will be safer to eat from the standpoint of bacterial contamination.*
- *There will be a definite increase of clean water of ready access to the urban communities of the Basin.*
- *A large portion of the Merrimack River will become available for recreation.*
- *The waters of the Basin will have increased c arity and less odor.*

EPA – STATE IMPLEMENTATION PROGRAM
FOR WATER POLLUTION ABATEMENT
LEGEND
WATER POLLUTION CONTROL FACILITY – SECONDARY TREATMENT
Constructed, Under Construction or Definitely Planned
In Preliminary Planning
MT. WASHINGTON
PEMIGEWASSET RIVER
LINCOLN
WARREN
WENTWORTH
RUMNEY
PLYMOUTH
SQUAM LAKE
MOULTONBORO
ASHLAND
NEWFOUND LAKE
BRISTOL
NEW HAMPTON
THE WEIRS
LAKE WINNIPESAUKEE
WOLFBORO
NEW HAMPSHIRE
MAINE
GRAFTON
WINNISQUAM LAKE
SANBORNTON
LACONIA
DANBURY
TILTON
WINNIPESAUKEE RIVER
BLACK WATER RIVER
BELMONT
ALTON
FRANKLIN
NORTHFIELD
GILMANTOWN
SANFORD
NEW LONDON
SALMON FALLS RIVER
MERRIMACK RIVER
PITTSFIELD
PENACOOK
PENACOOK
ROCHESTER
BERWICK
BRADFORD
SUNCOOK RIVER
SOMERSWORTH
PENACOOK LAKE
CONCORD
CONCORD
DOVER
HENNIKER
PEMBROKE
SUNCOOK
SUNCOOK
GREAT BAY
HILLSBORO
HOOKSETT
HOOKSETT
GOFFSTOWN
PORTSMOUTH


FRANKLIN
NORTHFIELD
BELMONT
GILMANTOWN
ALTON
SANFORD
NEW LONDON
BLACK WATER RIVER
WINNIPESAUKEE RIVER
MERRIMACK RIVER
PITTSFIELD
SALMON FALLS RIVER
ROCHESTER
BERWICK
SOMERSWORTH
DOVER
BRADFORD
PENACOOK
PENACOOK LAKE
SUNCOOK RIVER
CONCORD
HENNIKER
PEMBROKE
SUNCOOK
GREAT BAY
HILLSBORO
HOOKSETT
PORTSMOUTH
GOFFSTOWN
PISCATAQUOG RIVER
MANCHESTER
MASSABESIC LAKE
BEDFORD
KINGSTON
HANCOCK
DUBLIN
CONTOOCOOK RIVER
AMESBURY
ATLANTIC OCEAN
PETERBOROUGH
LONDONDERRY
DERRY
ISLAND POND
WILTON
MERRIMACK
ARLINGTON MILL RESERVOIR
WINDHAM
SOUHEGAN RIVER
LITCHFIELD
SALEM
CANOBIE LAKE
HAVERHILL
RIVER
JAFFREY
PENNICHUCK POND
COBBETTS POND
NEWBURYPORT
GREENVILLE
SPICKETT RIVER
HUDSON
NASHUA
LAWRENCE
NEW HAMPSHIRE
MASSACHUSETTS
LOWELL
ANDOVER
ASHBURNHAM
PEPPERELL
FITCHBURG
FITCHBURG – WEST
LUNENBURG
CHELMSFORD
WESTMINSTER
FITCHBURG – EAST
AYER
BILLERICA
SHAWSHEEN RIVER
PARTIALLY ADVANCED TREATMENT
NASHUA RIVER
FT. DEVENS
LEOMINSTER
2 PLANTS – 1 SITE
CONCORD RIVER
BEDFORD
CLINTON
MAYNARD
HOLDEN
HUDSON
MARLBOROUGH
WACHUSETT RESERVOIR
SUDBURY RESERVOIR
WAYLAND
BOSTON
BOSTON HARBOR
NORTHBORO
WESTBORO
BROOKLINE
FRAMINGHAM
NORTH
GRAPHIC SCALE
4 0 4 8 MILES

EPA-STATE IMPLEMENTATION PROGRAM

Selection Criteria:

- Applies well-established technologies
- Has institutional simplicity
- Represents minimal capital investment to satisfy existing regulations
- Places some reliance on the assimilative capacity of the river
- Meets in-stream water quality criteria according to "reasonable judgment"

Design Criteria:

- Designed for municipal, industrial, and very limited stormwater volumes projected to 1990.

Scheme Components:

Basic

▲ Fifteen activated sludge waste-
△ water treatment plants, either completed, under construction, definitely proposed, or in preliminary planning (not including the Winnipesaukee River Area).

Basic-Partially Advanced

▲ One activated sludge wastewater treatment plant with carbon adsorption facilities planned at Fitchburg-West.

Sludge disposal by sanitary land fill, or incineration.

Area Systems:

Winnipesaukee Area —
Regional concepts are presently being studied. Possibility of from one to three facilities, in any combination of secondary and advanced waste treatment schemes.

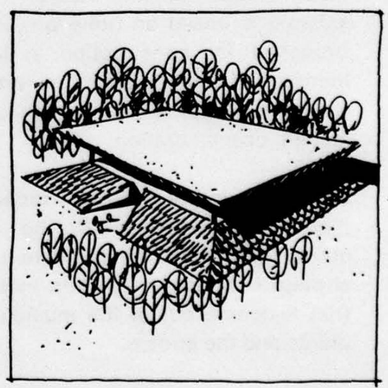
Concord Area —
Four activated sludge facilities, one under construction in the village of Penacook to serve Boscawen-north Concord areas, one proposed for the Concord-Bow area, one in preliminary planning for the village of Suncook to serve Pembroke-Allenstown area, and one completed to serve Hooksett.

Manchester Area —
One activated sludge facility to serve the region, is in preliminary planning.

Nashua Area —
Two activated sludge facilities, one completed to serve Merrimack and one under construction to serve the Nashua-Hudson area. The current construction in the Nashua-Hudson area will provide expanded primary treatment facilities. Secondary activated sludge treatment is planned for a subsequent date.

Fitchburg-Leominster Area —
Three treatment facilities; two activated sludge plants, one completed in Leominster (two plants at one site), and one planned in Fitchburg (East plant); and one advanced carbon adsorption facility planned in Fitchburg (West plant). Westminster and Lunenburg can be included in the Fitchburg facilities as needed.

Lowell-Lawrence-Haverhill Area —
Six activated sludge treatment facilities, two planned to serve Chelmsford, one proposed to serve the Lowell-Tewksbury-Dracut area, one completed in Billerica, one proposed to serve the Lawrence-Andover-North Andover-Methuen area, and one proposed to serve the Haverhill-Groveland area.



Architectural potential for a Wastewater Plant

Discussion

The EPA-State implementation program covers the entire basin but only those portions of the program pertaining to the urban areas studied are discussed here. Overall cost of the scheme is approximated based on a mixture of well defined costs for treatment facilities already designed, preliminary estimates and best judgment. Treatment facilities and interceptor sewers are included in the cost estimates.

Basically, the implementation scheme proposes provision of regional secondary treatment facilities to service each of the six urban areas under study. The EPA-State scheme does not propose interconnection of the six urban areas selected for wastewater management studies in the Basin. The scheme is based on State projects proposed for construction in furtherance of water quality standards. Sludge disposal will be by sanitary landfill, or incineration.

Industrial waste should receive thorough pretreatment, to be required through strict enforcement of sewage ordinances, to keep industrial toxicants out of the municipal plants and the stream.

This plan, representing the foundation upon which comprehensive basin-wide treatment systems could be built, relies heavily on the activated sludge process to produce effluent with the following characteristics:

Constituent	Concentration (PPM)
BOD	25
SS	25
COD	70
N	20
P	10
TDS	275

This scheme is now in the implementation stage. Fourteen Plants are definitely proposed, under construction, or have been completed. Considerable momentum has been built up under strong State-Federal pressure to complete this program by 1975.

Treated wastewater discharges will be returned to the streams near the treatment plants, except at Fitchburg West where a portion of the water will be returned for industrial reuse.

In addition to the general impacts of a clean-up program previously listed, there are specific impacts which characterize this program. Some of them are listed here:

- *The removal of pollutants from streams will favorably affect ecosystem stability but nutrients remaining in the discharges provide potential for algae blooms.*
- *People will be attracted to the Basin by the improved qualities of the river.*
- *The waters of the Merrimack will be significantly improved in clarity, odor and taste.*
- *Recreational activities associated with the river will be considerably increased.*
- *The communities will take some pride in their cleaner river.*
- *The quality of water, land and related resources will be enhanced providing a better place to live.*
- *Cleaner water will exert a moderate effect on future land use development.*
- *There will be a significant increase in the fishery.*
- *Long run employment could increase since the Basin will be a better place to live and work.*
- *Industry and production will benefit.*
- *Land values will rise along the river.*
- *Tax base of river towns will improve.*

Recreation access

MERRIMACK WASTEWATER MANAGEMENT STUDY

EPA-STATE IMPLEMENTATION PROGRAM

ESTIMATED COST BREAKDOWN (CAPITAL EXPENDITURES)

LOCATION OF PROJECT	ESTIMATED COST
Lowell-Lawrence-Haverhill Area	$120,000,000
Fitchburg-Leominster Area	20,000,000
Nashua Area	30,000,000
Manchester Area	40,000,000
Concord Area	15,000,000
Winnipesaukee River Area	10,000,000
Total Estimated Cost	$235,000,000

The Environmental Protection Agency and the States Implementation Programs are based on Secondary Treatment Facilities in each area. The above costs include approximately 10% for contingencies, design, and supervision of construction; but do not include land costs.

MERRIMACK WASTEWATER MANAGEMENT STUDY

EPA-STATE IMPLEMENTATION PROGRAM

ESTIMATED ANNUAL OPERATING COSTS

ITEM	STUDY AREA						
	L-L-H	F-L	NASHUA	MANCHESTER	CONCORD	WINN. RIVER	TOTAL
1. Annual Operating, Maint. & Power Costs	$ 6.7	$ 1.1	$ 1.7	$ 2.3	$ .8	$ .6	$13.2
2. Interest and Amortization Cost (5⅜ %)*	8.1	1.4	1.9	2.7	1.0	.7	15.9
Totals	$14.8	$ 2.5	$ 3.6	$ 5.0	$ 1.8	$ 1.3	$29.0

* Based on a 30 year life.
Figures are in millions of dollars

ALTERNATIVE SCHEMES

The seven schemes developed in this investigation are organized according to water, land, and combination water-land oriented approaches to wastewater renovation.

Each scheme considers the existence of the EPA-State program. Where it is compatible with the technology used, the scheme incorporates the treatment facilities in operation or to be constructed under that program as an integral part, expanding them as needed to meet the increasing volume of stormwater runoff. Where they are not directly complementary to the technology considered, modifications are described so that these secondary treatment plants can become a part of the larger strategy.

Each scheme provides for the removal of pollutants beyond the level achievable with basic (secondary) treatment. Moreover, each strategy addresses all three classes of wastewater (municipal sewage, stormwater and residual industrial wastes discharged from pre-treatment facilities in-plant) and produces effluent of a quality high enough to be directly compatible with drinking water standards:

Water Oriented Technology Concentration in (PPM)		Land Oriented Technology Concentration in (PPM)	
BOD	< 2	BOD	< 2
SS	< 2	SS	< 2
COD	< 5	COD	5-10
N	< 1	N	5
P	< 1	P	< 1
TDS	<100	TDS	330

All the schemes are based on design capacities derived from wastewater flows projected for the year 1990 in the following Basin subregions:

Winnipesaukee River Area:
Northfield, Franklin, Tilton, Sanbornton, Belmont, Laconia.

Concord Area:
Concord, Penacook, Bow, Hooksett, and Pembroke.

Manchester Area:
Manchester, Goffstown and Bedford.

Nashua Area:
Nashua, Hudson and Merrimack.

Fitchburg-Leominster Area:
Fitchburg, Lunenburg, Leominster and Westminster.

Lowell-Lawrence-Haverhill Area:
Lowell, Lawrence, Haverhill, Andover, Groveland, Methuen, North Andover, Billerica, Chelmsford, Dracut and Tewskbury.

All solution profiles are presented in a uniform format. *Selection criteria* point up major differences between alternatives and reflect the effort of the study team to offer a range of technical solutions and corresponding impacts. *Treatment components* is the total roster of techniques and processes used in a given solution while *Area Systems* allocates those totals by sub-region. In each case, the disposition of stormwater and sludge are described along with estimates of transmission distances for conveyance lines and effluent distribution piping where applicable. Tables which break out costs by construction and operation and

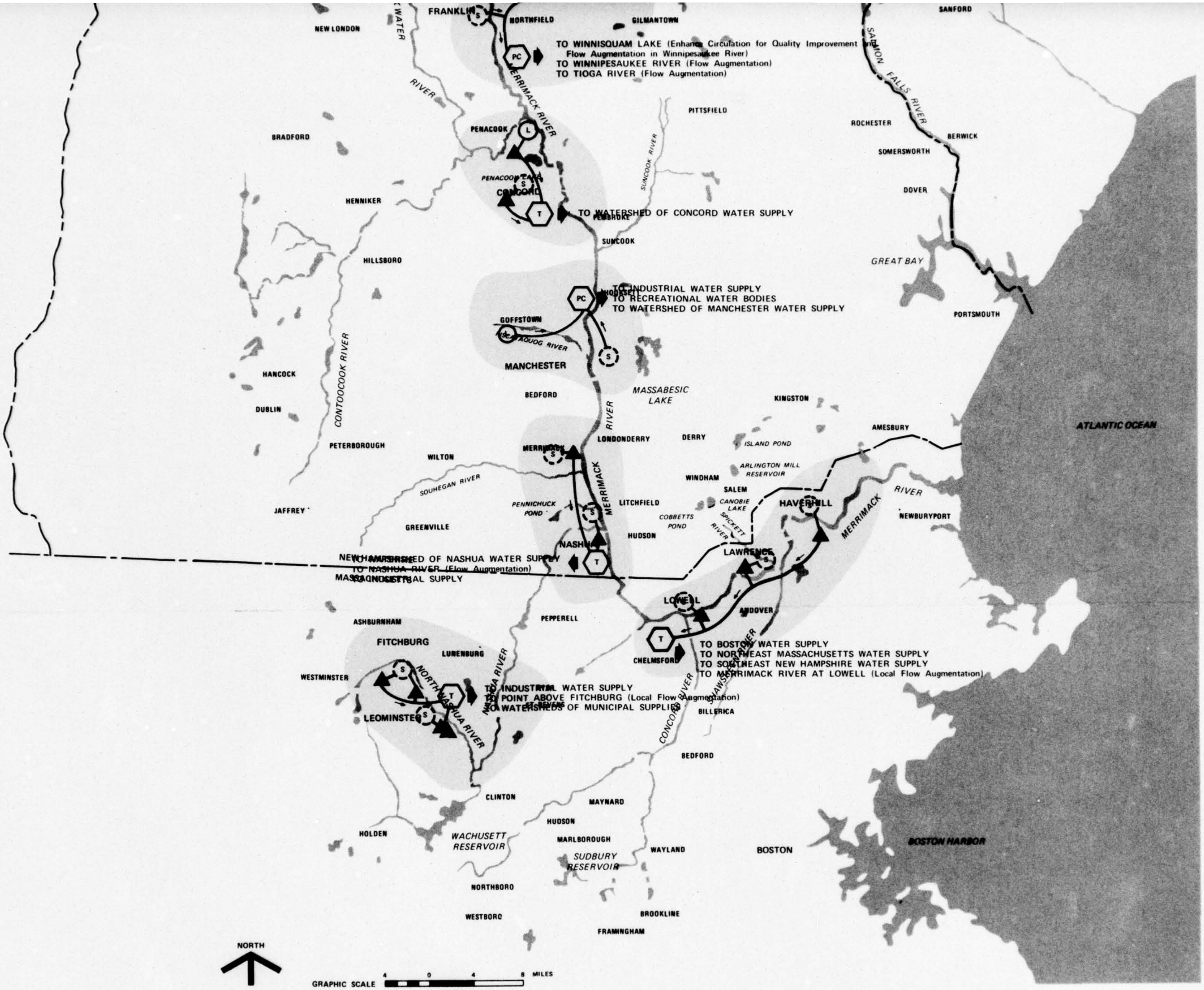
$<$ Symbol for less than

maintenance expenses are appended. These vital statistics are then expanded in a section which discusses the operation of the system as a whole, noting as a conclusion the uses to which wastewater purified by each solution could be put. Finally, an inventory of changes likely to issue from each solution is presented.

As each of these seven schemes produce many similar effects and include many similar devices it is only natural that certain impacts occur due to all seven. Some of these impacts common to all seven schemes in addition to those resulting from a general cleanup are listed here.

- *The removal of pollutants from streams will greatly increase species diversity and ecosystem stability.*
- *Eutrophication in Lake Winnisquam will be retarded.*
- *Removal of nutrients from the effluents will reduce the potential of algae problems.*
- *Viruses in Merrimack water will be significantly reduced.*
- *The waters of the Merrimack will be greatly improved in clarity, odor and taste.*
- *Local flooding from stormwater runoff backing up in sewers will be greatly reduced.*
- *Recreational activities associated with the River will be renewed.*
- *The communities will take considerable pride in their cleaner river.*
- *Water, land and related resource qualities will be greatly enhanced providing a much better place to live.*
- *Cleaner water will exert a powerful effect on future land use development.*
- *Many people will be attracted to the Basin by the significantly improved qualities of the River.*
- *The Merrimack will be a very much improved source of water.*
- *There will be a significant increase in the commercial fish and shellfish industry.*
- *Industry and production will markedly benefit.*
- *Long term employment will increase since the Basin will be a much better place to live and work.*
- *Land values will rise considerably along the river.*
- *Tax base of river towns will improve significantly.*


SCHEME NO. 1 – DECENTRALIZED, WATER ORIENTED SYSTEM
LEGEND
REGIONAL WASTEWATER TREATMENT FACILITY
T – Tertiary Treatment
PC – Physical-Chemical Treatment
WATER POLLUTION CONTROL FACILITY
Definitive Element in EPA – State Implementation Program
SURFACE LAGOON (Temporary Storage for Combined Sewage)
UNDERGROUND TUNNEL OR CHAMBER (Temporary Storage for Combined Sewage)
NOTE
Selection of one or more water uses shown is optional.
MT. WASHINGTON
LINCOLN
PEMIGEWASSET RIVER
WARREN
WENTWORTH
RUMNEY
PLYMOUTH
SQUAM LAKE
MOULTONBORO
ASHLAND
NEWFOUND LAKE
BRISTOL
NEW HAMPTON
THE WEIRS
LAKE WINNIPESAUKEE
WOLFBORO
GRAFTON
WINNISQUAM LAKE
SANBORNTON
LACONIA
DANBURY
TILTON
BELMONT
ALTON
FRANKLIN
NORTHFIELD
GILMANTOWN
NEW LONDON
BLACK WATER RIVER
TO WINNISQUAM LAKE (Enhance Circulation for Quality Improvement and Flow Augmentation in Winnipesaukee River)
TO WINNIPESAUKEE RIVER (Flow Augmentation)
TO TIOGA RIVER (Flow Augmentation)
MERRIMACK RIVER
PITTSFIELD
BRADFORD
PENACOOK
PENACOOK LAKE
CONCORD
SUNCOOK RIVER
HENNIKER
TO WATERSHED OF CONCORD WATER SUPPLY
SUNCOOK
HILLSBORO
TO INDUSTRIAL WATER SUPPLY
TO RECREATIONAL WATER BODIES
TO WATERSHED OF MANCHESTER WATER SUPPLY
NEW HAMPSHIRE
MAINE
SANFORD
SALMON FALLS RIVER
ROCHESTER
BERWICK
SOMERSWORTH
DOVER
GREAT BAY
PORTSMOUTH


TO WINNISQUAM LAKE (Enhance Circulation for Quality Improvement and Flow Augmentation in Winnipesaukee River)
TO WINNIPESAUKEE RIVER (Flow Augmentation)
TO TIOGA RIVER (Flow Augmentation)
TO WATERSHED OF CONCORD WATER SUPPLY
TO INDUSTRIAL WATER SUPPLY
TO RECREATIONAL WATER BODIES
TO WATERSHED OF MANCHESTER WATER SUPPLY
TO WATERSHED OF NASHUA WATER SUPPLY
TO NASHUA RIVER (Flow Augmentation)
TO INDUSTRIAL SUPPLY
TO BOSTON WATER SUPPLY
TO NORTHEAST MASSACHUSETTS WATER SUPPLY
TO SOUTHEAST NEW HAMPSHIRE WATER SUPPLY
TO MERRIMACK RIVER AT LOWELL (Local Flow Augmentation)
TO INDUSTRIAL WATER SUPPLY
TO POINT ABOVE FITCHBURG (Local Flow Augmentation)
TO WATERSHEDS OF MUNICIPAL SUPPLIES
NEW HAMPSHIRE
MASSACHUSETTS
FRANKLIN
NORTHFIELD
GILMANTOWN
NEW LONDON
PITTSFIELD
SANFORD
ROCHESTER
BERWICK
SOMERSWORTH
DOVER
SALMON FALLS RIVER
MERRIMACK RIVER
BRADFORD
PENACOOK
PENACOOK LAKE
CONCORD
HENNIKER
PEMBROKE
SUNCOOK
SUNCOOK RIVER
GREAT BAY
PORTSMOUTH
HILLSBORO
GOFFSTOWN
PISCATAQUOG RIVER
MANCHESTER
HANCOCK
DUBLIN
CONTOOCOOK RIVER
BEDFORD
MASSABESIC LAKE
KINGSTON
ATLANTIC OCEAN
AMESBURY
PETERBOROUGH
WILTON
MERRIMACK
LONDONDERRY
DERRY
ISLAND POND
ARLINGTON MILL RESERVOIR
WINDHAM
SALEM
SOUHEGAN RIVER
PENNICHUCK POND
LITCHFIELD
COBBETTS POND
CANOBIE LAKE
SPICKETT RIVER
HAVERHILL
RIVER
NEWBURYPORT
JAFFREY
GREENVILLE
HUDSON
NASHUA
LAWRENCE
LOWELL
ANDOVER
PEPPERELL
ASHBURNHAM
FITCHBURG
LUNENBURG
CHELMSFORD
WESTMINSTER
NORTH NASHUA RIVER
NASHUA RIVER
LEOMINSTER
CONCORD RIVER
BILLERICA
BEDFORD
CLINTON
MAYNARD
HOLDEN
WACHUSETT RESERVOIR
MARLBOROUGH
SUDBURY RESERVOIR
WAYLAND
BOSTON
BOSTON HARBOR
NORTHBORO
WESTBORO
BROOKLINE
FRAMINGHAM
NORTH
GRAPHIC SCALE
4 0 4 8 MILES
PC
L
S
T

2

SCHEME NO. 1: DECENTRALIZED, WATER ORIENTED SYSTEM

Selection Criteria:

- Simplifies institutional arrangements
- Utilizes definitive portions of the current implementation program
- Causes minimum disruption of the natural stream flow regime of the Merrimack Basin
- Achieves limited economies of scale (single advanced treatment systems for each major area)
- Takes advantage of advanced water oriented technology

Design Criteria:

- Designed for municipal, industrial and stormwater volumes projected to 1990 (including a storm with 2.6″ rainfall in 6 hours)

Scheme Components:

Basic

▲ Ten activated sludge wastewater treatment plants with sludge digestion and dewatering facilities

Advanced

(T) Four regional tertiary wastewater treatment plants with sludge dewatering facilities

(PC) Two regional physical-chemical *wastewater treatment plants with* sludge digestion and dewatering facilities

(S) Ten subsurface storage chambers
(L) and five surface lagoons for temporary storage of stormwater runoff and combined sewer flow

Approximately 129 miles of underground sewage transmission pipes and tunnels

Sludge produced by both basic and advanced treatment will be applied to farm lands proximate to each area. Brines will be evaporated, stored, and periodically disposed of at sea.

Area Systems: 6

Winnipesaukee Area

One regional (PC) at Franklin, New Hampshire — 34 MGD capacity

Three (L) one each at Laconia, Belmont and Tilton — 144 MG, 10 MG, and 125 MG

One (S) at Franklin — 47 MG capacity

Transmission system connecting all areas to (PC) at Franklin — 19 miles

Concord Area

Two ▲ one each at Concord and Penacook — 25 MGD and 6 MGD capacity

One regional (T) at Concord — 31 MGD capacity

One (L) at Penacook — 50 MG capacity

One (S) at Concord — 209 MG capacity

Transmission system connecting all areas to (T) at Concord — 15 miles

Manchester Area

One (PC) at Manchester — 52 MGD capacity

One (S) at Manchester — 227 MG capacity

One (L) near Goffstown — 37 MG capacity

Transmission tunnel for sewage and stormwater connecting all areas to (PC) at Manchester — 10 miles

Nashua Area

Two ▲ one each at Nashua and Merrimack — 36 MGD and 14 MGD capacity

One regional (T) at Nashua — 50 MGD capacity

Two (S), one each at Nashua and Merrimack — 216 MG and 94 MG capacity

Transmission tunnel for sewage and stormwater connecting all areas to Ⓣ at Nashua — 16 miles

Fitchburg-Leominster Area

Three ▲ , two at Fitchburg and one at Leominster — 15 MGD, 32 MGD and 17 MGD capacity

One regional Ⓣ at Leominster — 64 MGD capacity

Two Ⓢ , one each at Fitchburg and Leominster — 278 MG and 82 MG capacity

Transmission tunnel for sewage and stormwater to Ⓣ at Leominster — 21 miles

Lowell-Lawrence-Haverhill Area

Three ▲ , one each at Lowell, Lawrence and Haverhill — 49 MGD, 64 MGD and 32 MGD capacity

One Ⓣ at Lowell — 145 MGD capacity

Three Ⓢ , one each at Lowell, Lawrence and Haverhill — 277 MG, 307 MG and 149 MG capacity

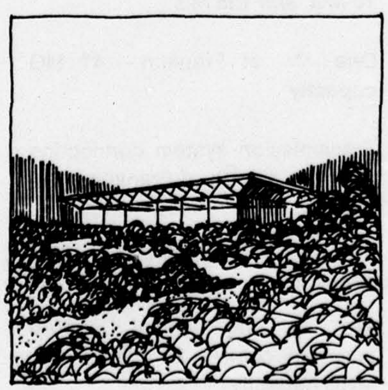
Transmission tunnel for sewage and stormwater to Ⓣ at Haverhill or Lowell — 48 miles

Discussion

The first of the three water oriented schemes recognizes the interconnection of contiguous communities within each area for their mutual benefit, but *it does not consider* the interconnection of the six study regions themselves. Since many, though not all, of the municipalities currently have combined sewers, it was considered reasonable to combine municipal, industrial, and stormwater flows.

In the Winnipesaukee Region all the collected wastewaters would be transported to a regional physical-chemical treatment facility at Franklin. Thus, the nutrients presently discharged by Laconia would not be able to enter Lake Winnisquam, a large body with a rapidly progressing eutrophication problem.

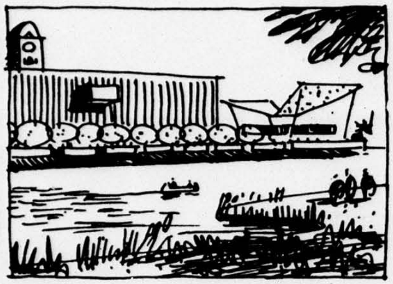
In the Concord Region which is composed of the municipalities of Hooksett, Penacook, Suncook, Pembroke, Bow, and Concord, only Hooksett has a small existing secondary treatment facility. Two additional secondary treatment facilities would be constructed, one in the north of Concord and one on the *south side of town*, consistent with the state implementation schedule. These two plants would receive and treat all wastewaters with the exception of a small part of the wastewater flow from Hooksett. All treated effluents from these three secondary units would be transported to a regional tertiary plant on the south side of Concord.



Architectural potential for a Wastewater Plant

Manchester and the two nearby towns of Bedford and Goffstown would be serviced by a single large physical-chemical treatment facility located just south of Manchester.

In the Nashua Region, only Merrimack has a secondary treatment facility and this plant presently receives *basically industrial* wastewater from a brewery. Nashua presently has a partial primary treatment with proposed secondary treatment. This scheme includes a regional tertiary plant located just south of the city to receive the secondary effluent from the Merrimack and Nashua plant.



New life to the riverscape

Use of the recently expanded Leominster wastewater treatment facility is retained. The existing secondary plant in Fitchburg which is presently considered inadequate due to overloading, is to be supplemented by a new secondary plant. The wastewater effluent from these three treatment facilities is pumped to a regional tertiary plant in the vicinity of the existing Leominster treatment plant.

Lowell, Lawrence, and Haverhill will each have a secondary biological treatment facility. This scheme suggests that those three municipalities be consolidated into a single sanitary district with interconnection being made so that the effluent from the secondary treatment plants can be delivered to a regional tertiary plant located above Lowell.

Any additional secondary treatment facility which might be constructed can be readily connected to this arrangement. In this scheme those plants now definitively developed in the EPA-State implementation program are included. This is an important factor as it would utilize the momentum now built up by the efforts of the states to speed completion of the program. This together with treating each of the six areas individually would simplify the institutional arrangements needed for implementation. The high quality water produced by the advanced wastewater treatment plants could be used in various ways. Listed on page 58 are some of its possible uses. Costs for making these uses possible are not included in the scheme's cost estimate.

All the impacts listed for a general stream improvement program and all those listed as being common to the seven alternative schemes are likely to occur. In addition, impacts specific to this scheme are:

- ***A major disturbance will occur in the terrestrial environment at plant sites.***
- ***There will be some disruption of the scenery at plant sites during construction.***
- ***Imaginative design of facilities can develop a potential for multiple use: parks, public buildings, gardens.***
- ***Sludge disposal on land will provide a source of plant nutrients and act as a soil conditioner.***
- ***Employment during construction of the wastewater facilities will increase.***

POTENTIAL USES FOR RECLAIMED WATER — SCHEME 1

WINNIPESAUKEE — 24 MGD (Average)

- *Flow augmentation in the Tioga River.*
- *Diversion to the head of Lake Winnisquam to enhance circulation of the lake, and flow augmentation in the Winnipesaukee River.*
- *Return to the Winnipesaukee River above Tilton.*
- *Containment of the reclaimed water to serve as new recreational water bodies.*

CONCORD — 24 MGD (Average)

- *Return to the municipal watershed in order to supplement the existing water supply.*
- *Return to existing or newly created recreational water bodies.*
- *Flow augmentation in the Soucook River.*

MANCHESTER — 45 MGD (Average)

- *Return to the watershed area around Lake Massabesic to supplement the water supply.*
- *Transfer to Southeast New Hampshire for water supply.*
- *Reuse in industries such as textiles and tanneries.*
- *Flow augmentation in the Piscataquog River.*
- *Containment of the reclaimed water to serve as new recreational water bodies.*
- *Return to Merrimack River to maintain natural flow regime.*

NASHUA — 40 MGD (Average)

- *Return to Pennichuck Pond for supplementation of Nashua's water supply.*
- *Reuse for industrial process water.*
- *Flow augmentation in the Nashua River.*
- *Return to Merrimack River to maintain natural flow regime.*

FITCHBURG-LEOMINSTER — 54 MGD (Average)

- *Reuse in industries such as paper and plastics.*
- *Return for increase of the municipal water supply.*
- *Return upstream for localized flow augmentation.*

LOWELL-LAWRENCE-HAVERHILL — 122 MGD (Average)

- *Transfer to southeastern New Hampshire water supply (relocate tertiary plant at Haverhill).*
- *Transfer to Boston for water supply.*
- *Return to the Merrimack River at Lowell for localized flow augmentation.*
- *Reuse for industrial process water in tanning and paper.*
- *Transfer to northeastern Massachusetts for water supply (relocate tertiary plant at Haverhill).*

MERRIMACK WASTEWATER MANAGEMENT STUDY
ESTIMATED COST BREAKDOWN (CAPITAL EXPENDITURES)

Scheme No. 1 Decentralized, Water Oriented System

Items	L-L-H	Nashua	F-L	Manchester	Concord	Winn. River	Totals
Construction							
Conveyance System	$ 18.0	$ 1.0	$ 2.5	$ 5.5	$ 1.0	$ 3.0	$ 30.0
Stormwater Storage	122.0	52.0	59.0	40.0	35.0	10.0	318.0
Basic Treatment	65.0	23.0	35.0	—	16.0	—	139.0
Advanced Treatment	43.0	18.0	22.5	18.5	13.0	13.0	128.0
Sub-Total	248.0	94.0	119.0	63.0	65.0	26.0	615.0
Const. Contingencies (20%)	50.0	19.0	24.0	13.0	13.0	5.0	124.0
Sub-Total	298.0	113.0	143.0	76.0	78.0	31.0	739.0
Superv. & Admin.* (8%)	24.0	9.0	12.0	6.0	6.0	3.0	60.0
Sub-Total	322.0	122.0	155.0	82.0	84.0	34.0	799.0
Engineering** (10%)	29.8	11.3	14.3	7.5	7.8	3.0	73.7
Sub-Total	351.0	133.3	169.3	89.6	91.8	37.0	872.7
Land Acquisition	0.8	0.4	0.4	0.4	0.5	0.5	3.0
Totals	352.6	133.7	169.7	90.0	$92.3	37.5	875.8
Say	$352.0	$134.0	$170.0	$90.0	$92.0	$38.0	$876.0

* 8% of Construction and Contingencies
** 10% of Construction and Contingencies

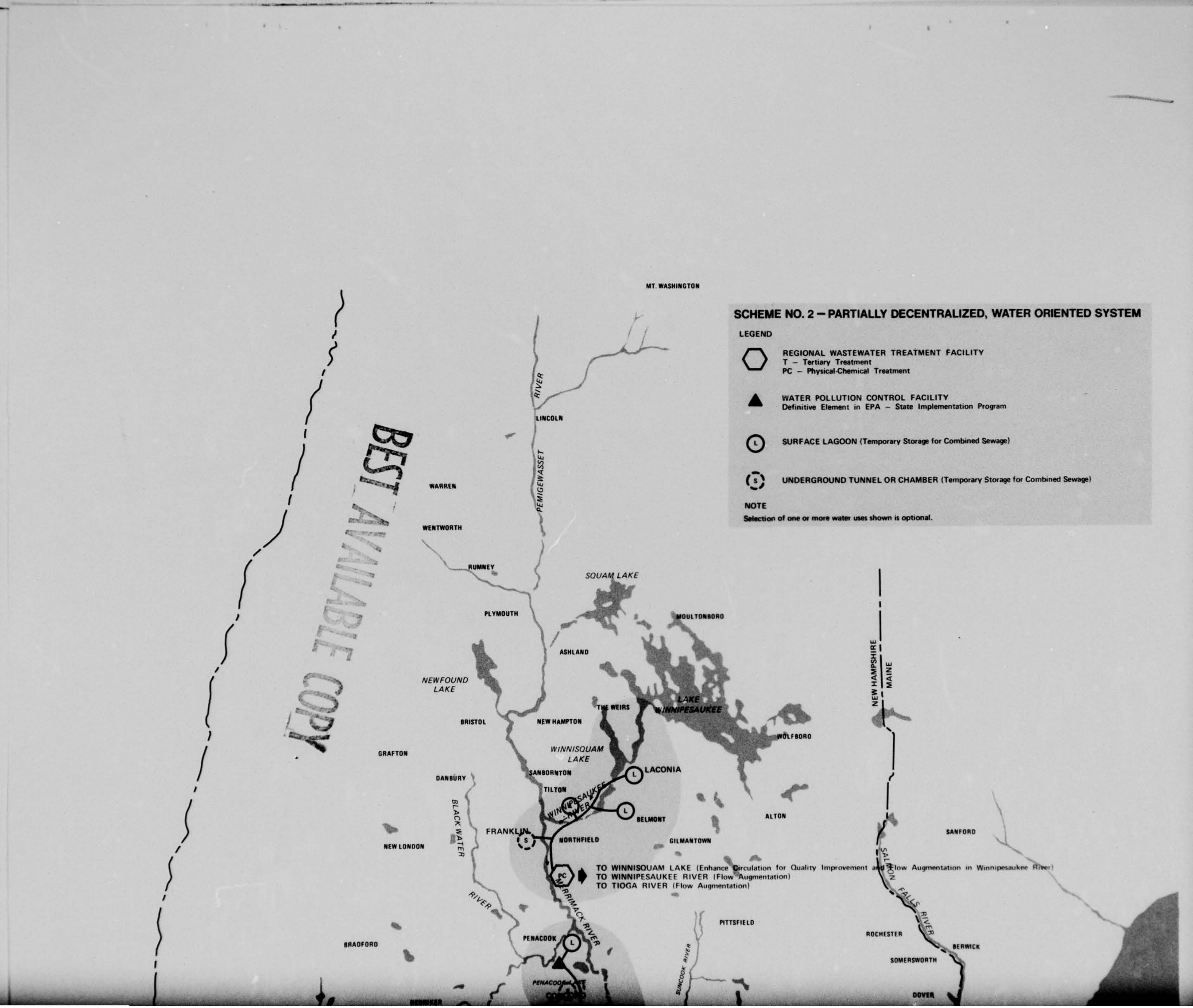
Notes:
1. Figures are in Millions of Dollars
2. Costs of schemes for reuse of renovated water are not included above
3. ENR = 1500
4. In addition to the large tunnel and pipe lines described in "Area Systems," the conveyance costs also include wastewater collection from the satellite communities in each of the six areas.

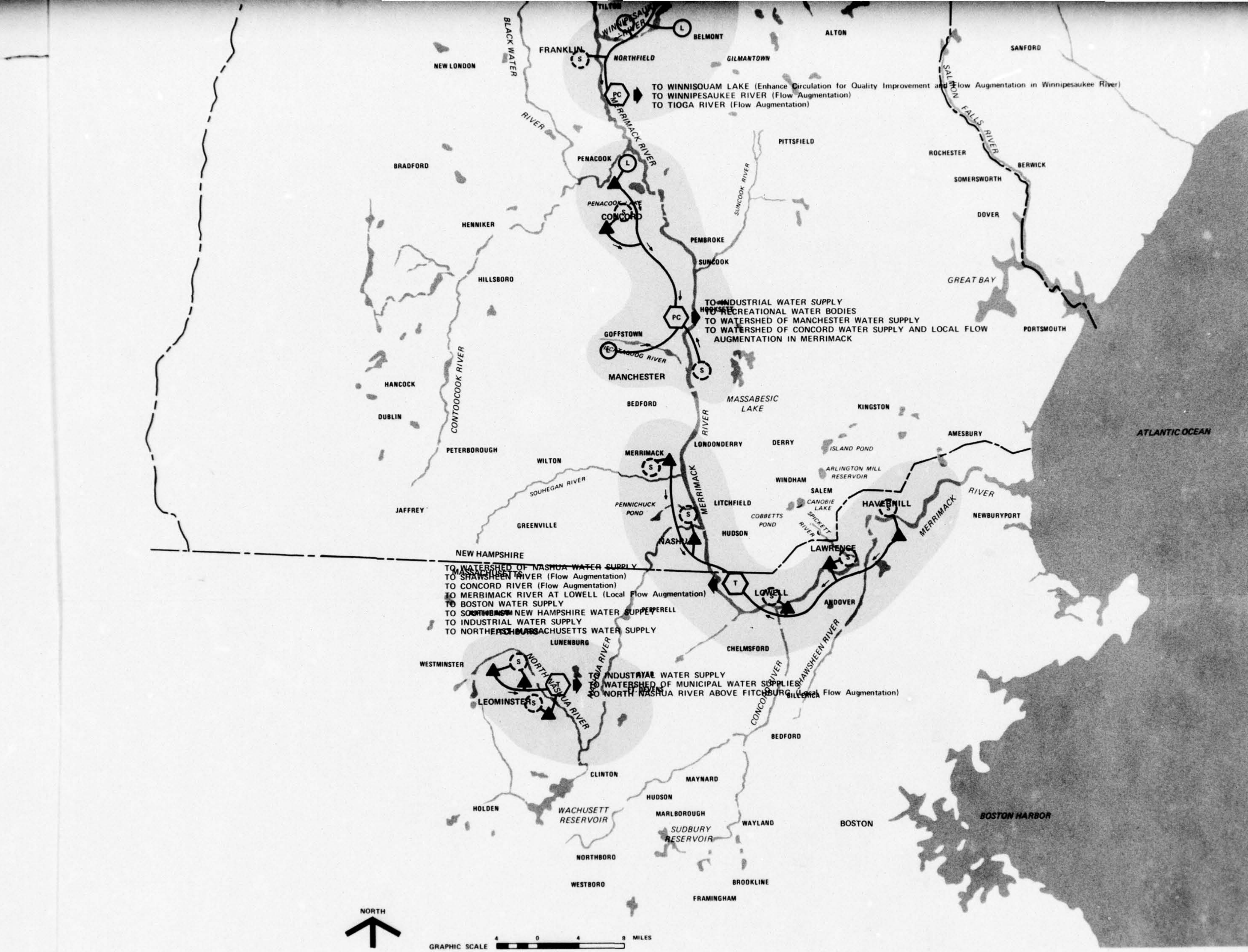
MERRIMACK WASTEWATER MANAGEMENT STUDY
ESTIMATED ANNUAL OPERATING COSTS

Scheme No. 1 Decentralized, Water Oriented System

Items	L-L-H	Nashua	F-L	Manchester	Concord	Winn. River	Totals
1. Annual operating maint. & power cost	$19.5	$ 7.0	$ 9.0	$ 6.0	$ 4.7	$ 3.3	$49.5
2. Annual interest and amortization on capital costs* 5⅜%							
Pipe in place, tunnels, chambers a. Based on 50 yr. life	9.4	3.7	4.2	3.1	2.5	.9	23.8
Plants, pump stations, lagoons etc. b. Based on 30 yr. life	9.5	3.4	4.9	1.6	2.4	1.0	22.8
Irrigation Systems c. Based on 20 yr. life	—	—	—	—	—	—	—
Estimated Annual d. Amortization Cost	18.9	7.1	9.1	4.7	4.9	1.9	46.6
Total Estimated e. Annual operating, Maintenance & amortization	38.4	14.1	18.1	10.7	9.6	5.2	96.1
f. Say	$38.5	$14.0	$18.0	$11.0	$ 9.5	$ 5.0	$96.0

* Figures are based on the estimated construction cost and 20% contingencies
Figures are in Millions of Dollars


MT. WASHINGTON
SCHEME NO. 2 — PARTIALLY DECENTRALIZED, WATER ORIENTED SYSTEM
LEGEND
REGIONAL WASTEWATER TREATMENT FACILITY
T – Tertiary Treatment
PC – Physical-Chemical Treatment
WATER POLLUTION CONTROL FACILITY
Definitive Element in EPA – State Implementation Program
SURFACE LAGOON (Temporary Storage for Combined Sewage)
UNDERGROUND TUNNEL OR CHAMBER (Temporary Storage for Combined Sewage)
NOTE
Selection of one or more water uses shown is optional.
PEMIGEWASSET RIVER
LINCOLN
WARREN
WENTWORTH
RUMNEY
PLYMOUTH
SQUAM LAKE
MOULTONBORO
ASHLAND
NEWFOUND LAKE
BRISTOL
NEW HAMPTON
THE WEIRS
LAKE WINNIPESAUKEE
WOLFBORO
GRAFTON
DANBURY
WINNISQUAM LAKE
SANBORNTON
TILTON
LACONIA
WINNIPESAUKEE RIVER
BELMONT
ALTON
FRANKLIN
NORTHFIELD
GILMANTOWN
NEW LONDON
BLACK WATER RIVER
TO WINNISQUAM LAKE (Enhance Circulation for Quality Improvement and Flow Augmentation in Winnipesaukee River)
TO WINNIPESAUKEE RIVER (Flow Augmentation)
TO TIOGA RIVER (Flow Augmentation)
MERRIMACK RIVER
PITTSFIELD
BRADFORD
PENACOOK
PENACOOK LAKE
SUNCOOK RIVER
NEW HAMPSHIRE
MAINE
SANFORD
SALMON FALLS RIVER
ROCHESTER
BERWICK
SOMERSWORTH
DOVER
BEST AVAILABLE COPY



TO WINNISQUAM LAKE (Enhance Circulation for Quality Improvement and Flow Augmentation in Winnipesaukee River)
TO WINNIPESAUKEE RIVER (Flow Augmentation)
TO TIOGA RIVER (Flow Augmentation)
TO INDUSTRIAL WATER SUPPLY
TO RECREATIONAL WATER BODIES
TO WATERSHED OF MANCHESTER WATER SUPPLY
TO WATERSHED OF CONCORD WATER SUPPLY AND LOCAL FLOW AUGMENTATION IN MERRIMACK
TO WATERSHED OF NASHUA WATER SUPPLY
TO SHAWSHEEN RIVER (Flow Augmentation)
TO CONCORD RIVER (Flow Augmentation)
TO MERRIMACK RIVER AT LOWELL (Local Flow Augmentation)
TO BOSTON WATER SUPPLY
TO SOUTHERN NEW HAMPSHIRE WATER SUPPLY
TO INDUSTRIAL WATER SUPPLY
TO NORTHEASTERN MASSACHUSETTS WATER SUPPLY
TO INDUSTRIAL WATER SUPPLY
TO WATERSHED OF MUNICIPAL WATER SUPPLIES
TO NORTH NASHUA RIVER ABOVE FITCHBURG (Local Flow Augmentation)
ATLANTIC OCEAN
BOSTON HARBOR
GREAT BAY
MERRIMACK RIVER
BLACK WATER RIVER
CONTOOCOOK RIVER
SUNCOOK RIVER
SALMON FALLS RIVER
SOUHEGAN RIVER
NORTH NASHUA RIVER
CONCORD RIVER
SHAWSHEEN RIVER
SPICKETT RIVER
MASSABESIC LAKE
ISLAND POND
ARLINGTON MILL RESERVOIR
CANOBIE LAKE
COBBETTS POND
PENNICHUCK POND
PENACOOK LAKE
WACHUSETT RESERVOIR
SUDBURY RESERVOIR
NEW HAMPSHIRE
MASSACHUSETTS
TILTON
BELMONT
ALTON
SANFORD
FRANKLIN
NORTHFIELD
GILMANTOWN
NEW LONDON
PITTSFIELD
ROCHESTER
BERWICK
SOMERSWORTH
DOVER
BRADFORD
PENACOOK
CONCORD
HENNIKER
PEMBROKE
SUNCOOK
HILLSBORO
HOOKSETT
PORTSMOUTH
GOFFSTOWN
MANCHESTER
HANCOCK
DUBLIN
BEDFORD
KINGSTON
AMESBURY
PETERBOROUGH
LONDONDERRY
DERRY
WILTON
MERRIMACK
WINDHAM
SALEM
LITCHFIELD
HAVERHILL
NEWBURYPORT
JAFFREY
GREENVILLE
HUDSON
NASHUA
LAWRENCE
LOWELL
ANDOVER
PEPPERELL
FITCHBURG
LUNENBURG
CHELMSFORD
WESTMINSTER
LEOMINSTER
BILLERICA
BEDFORD
CLINTON
MAYNARD
HOLDEN
HUDSON
MARLBOROUGH
WAYLAND
BOSTON
NORTHBORO
BROOKLINE
WESTBORO
FRAMINGHAM
NORTH
GRAPHIC SCALE
4 0 4 8 MILES

SCHEME NO. 2: PARTIALLY DECENTRALIZED, WATER ORIENTED SYSTEM

Selection Criteria:

- Increases physical integration centralizing control over larger volumes of water
- Utilizes definitive portions of the existing implementation program
- Increases development opportunities between urban areas along the wastewater transmission routes
- Takes advantage of advanced water oriented technology

Design Criteria:

- Designed for municipal, industrial, and stormwater volumes projected to 1990 (including a storm with a 2.6" rainfall in 6 hours)

Scheme Components:

Basic

▲ Ten activated sludge wastewater treatment plants with sludge digestion and dewatering facilities

Advanced

Ⓣ Two regional tertiary wastewater treatment plants with sludge dewatering facilities

(PC) Two regional physical-chemical wastewater treatment plants with sludge digestion and dewatering facilities

Ⓢ Ten subsurface storage chambers and five surface lagoons for temporary storage of stormwater runoff and combined sewer flow

Ⓛ

Approximately 150 miles of sewage transmission pipes and tunnels

Sludge produced by both basic and advanced treatment will be applied to farm lands proximate to each area. Brines will be evaporated, stored and periodically disposed of at sea

Area Systems: 4

Winnipesaukee Area:

One regional (PC) at Franklin, New Hampshire — 34 MGD capacity

Three Ⓛ one each at Laconia, Belmont and Tilton — 144 MG, 10 MG, and 125 MG capacity

One Ⓢ at Franklin — 47 MG capacity

Transmission system connecting all areas to (PC) at Franklin — 19 miles

Concord-Manchester Area

Two ▲, one each at Penacook and Concord — 6 MGD and 25 MGD capacity

One regional (PC) at Manchester — 83 MGD capacity

Two Ⓛ, at Penacook and Goffstown — 50 MG and 37 MG capacity

Two Ⓢ, one each at Concord and Manchester — 209 MG and 227 MG capacity

Transmission system connecting all areas to (PC) at Manchester — 38 miles

Fitchburg-Leominster Area

Three ▲, two at Fitchburg and one at Leominster — 15 MGD, 32 MGD and 17 MGD capacity

One regional Ⓣ at Leominster — 64 MGD capacity

Two Ⓢ, one each at Leominster and Fitchburg — 82 MG and 278 MG capacity

Transmission system connecting all areas to Ⓣ at Leominster — 21 miles

Nashua-Lowell-Lawrence-Haverhill Area

Five ▲, one each at Merrimack, Nashua, Lowell, Lawrence and Haverhill — 14 MGD, 36 MGD, 49 MGD, 64 MGD and 32 MGD capacity

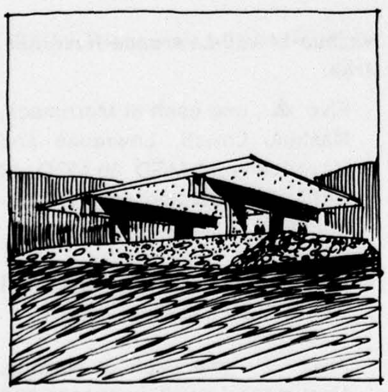
One regional Ⓣ west of Lowell — 195 MGD capacity

Five Ⓢ, one each at Nashua, Merrimack, Lowell, Lawrence and Haverhill — 216 MG, 94 MG, 277 MG, 307 MG and 149 MG capacity

Transmission system connecting all areas to Ⓣ at Lowell — 72 miles

Discussion

Scheme No. 2 can achieve a level of control unattainable in the more localized plan, yet does not require massive regionalization and interconnection. This plan also utilizes those elements of the implementation schedule which are supported by state and federally approved engineering reports. In this second plan, the configuration, which suggests an intermediate level of regionalization and interconnection, leads to fewer treatment facilities but with larger design capacities. This smaller number of advanced treatment facilities generally leads to better operation due to the need for fewer skilled crews. In addition, more centralized control over the treatment of larger volumes of water is possible. And this can improve treatment effectiveness as well as operational reliability.



Architectural potential for a Wastewater Plant

This scheme has been developed by interconnecting two of the smaller urban areas with adjacent larger municipalities. The four regions in Scheme No. 2 are:

Winnipesaukee Region

Concord-Manchester

Leominster-Fitchburg

Nashua-Lowell-Lawrence-Haverhill

The Winnipesaukee area in this scheme is treated identically to scheme 1 with a regional physical-chemical advanced waste treatment plant near Franklin.

The municipalities of Concord and Manchester have been considered as a single district to be served by a single regional physical-chemical advanced wastewater treatment facility located north of Manchester, treating raw wastewater from Manchester and the effluent from two activated sludge plants near Concord. These combined operations are possible due to the nature and arrangement of the unit processes in a physical-chemical wastewater treatment facility.

In this scheme the wastewaters from the Fitchburg-Leominster area are handled in the same way as in scheme 1.

Nashua has been combined with the Lowell-Lawrence-Haverhill area to comprise a major regional system which has the largest population and the greatest industrial diversity of any region in this scheme. The inclusion of a regional tertiary facility in the vicinity of Lowell is considered a logical extension of the present EPA-State implementation program if the high levels of water quality suggested in this study are to be realized.

Potential for a riverfront development

This scheme, just as scheme 1, includes the plants now definitively developed as part of the EPA-State implementation program. This will utilize the momentum now built up by the efforts of the states, to speed completion of the program. Coordination will be more complex because several interstate communities must participate. However, this opens opportunities for overall regional cooperation. The inter-city connections between the Concord and Manchester and the Nashua and Lowell-Lawrence-Haverhill areas present opportunities for land use management. The right-of-way of these pipelines would be used restrictively to insure an open space or can be used to channel development into a pre-determined corridor. Renovated water would be concentrated at four locations. Listed on page 64 are some of the possible uses. Cost for these uses are not included in the scheme's cost estimate.

In addition to impacts common to all schemes, those specific to this scheme are:

- *Creation of new suitable habitat along transmission pipes may increase the quantity of deer and other game.*
- *Cooperation between various communities and/or states will result in more effective decision processes.*
- *Transmission pipes to regional facilities will disrupt the landscape.*
- *The preservation of open space along transmission lines may increase the visual diversity of the landscape.*
- *There will be some disruption of the scenery at plant sites during construction.*
- *Major disturbance will occur in the terrestrial environment at plant sites.*
- *Employment during construction of the wastewater facilities will increase.*
- *Sludge disposal on land will provide a moderate source of plant nutrients and act as a soil conditioner.*
- *Imaginative design of facilities can develop a potential for multiple use.*

POTENTIAL USES FOR RECLAIMED WATER — SCHEME NO. 2

WINNIPESAUKEE — 24 MGD (Average)

- ***Flow augmentation in the Tioga River.***
- ***Diversion to the head of Lake Winnisquam to enhance circulation of the lake.***
- ***Return to the Winnipesaukee River above Tilton.***
- ***Containment of the reclaimed water to serve as new recreational water bodies.***

CONCORD-MANCHESTER — 69 MGD (Average)

- ***Return to the Concord and Manchester municipal watersheds to supplement the water supply.***
- ***Reuse in industries such as tanning and textiles.***
- ***Return to the Merrimack River to maintain natural flow regimes.***
- ***Return to existing or newly created recreational water bodies.***

FITCHBURG-LEOMINSTER — 54 MGD (Average)

- ***Reuse in industries such as paper and plastics.***
- ***Return to the municipal water supply.***
- ***Return upstream for localized flow augmentation.***

NASHUA-LOWELL-LAWRENCE-HAVERHILL — 162 MGD (Average)

- ***Transfer to southeastern New Hampshire water supply.***
- ***Reuse for industrial process water in industries such as textiles, paper, and tanning.***
- ***Transfer to Boston for water supply.***
- ***Flow augmentation in Nashua, Shawsheen and Concord Rivers.***
- ***Transfer to northeastern Massachusetts for water supply.***

MERRIMACK WASTEWATER MANAGEMENT STUDY
ESTIMATED COST BREAKDOWN (CAPITAL EXPENDITURES)

Scheme No. 2 Partially Decentralized, Water Oriented System

Item	L-L-H & Nashua	F-L	Manchester & Concord	Winn. River	Total
Construction					
Conveyance System	$ 25.0	$ 2.5	$ 8.4	$ 3.0	$ 38.9
Stormwater Storage	174.5	60.0	80.3	10.0	324.8
Basic Treatment	87.0	35.0	12.2	—	134.2
Advanced Treatment	54.5	22.5	28.1	13.0	118.1
Sub-Total	341.0	120.0	129.0	26.0	616.0
Const. Contingencies (20%)	68.0	24.0	27.0	5.0	124.0
Sub-Total	409.0	144.0	156.0	31.0	740.0
Superv. & Admin. (8%)*	32.0	12.0	12.5	3.0	60.0
Sub-Total	441.0	156.0	168.5	34.0	800.0
Engineering (10%)**	40.6	14.4	15.5	3.0	74.0
Sub-Total	481.6	170.4	184.0	37.0	874.0
Land Acquisition	1.2	0.4	1.0	0.5	3.0
Totals	482.8	170.8	185.0	37.5	877.0
Say	$483.0	$171.0	$185.0	$ 38.0	$877.0

* 8% of Construction and Contingencies
** 10% of Construction and Contingencies

Notes:
1. Figures are in Millions of Dollars
2. Costs of schemes for reuse of renovated water are not included above
3. ENR = 1500
4. In addition to the large tunnel and pipe lines described in "Area Systems," the conveyance costs also include wastewater collection from the satellite communities in each of the six areas.

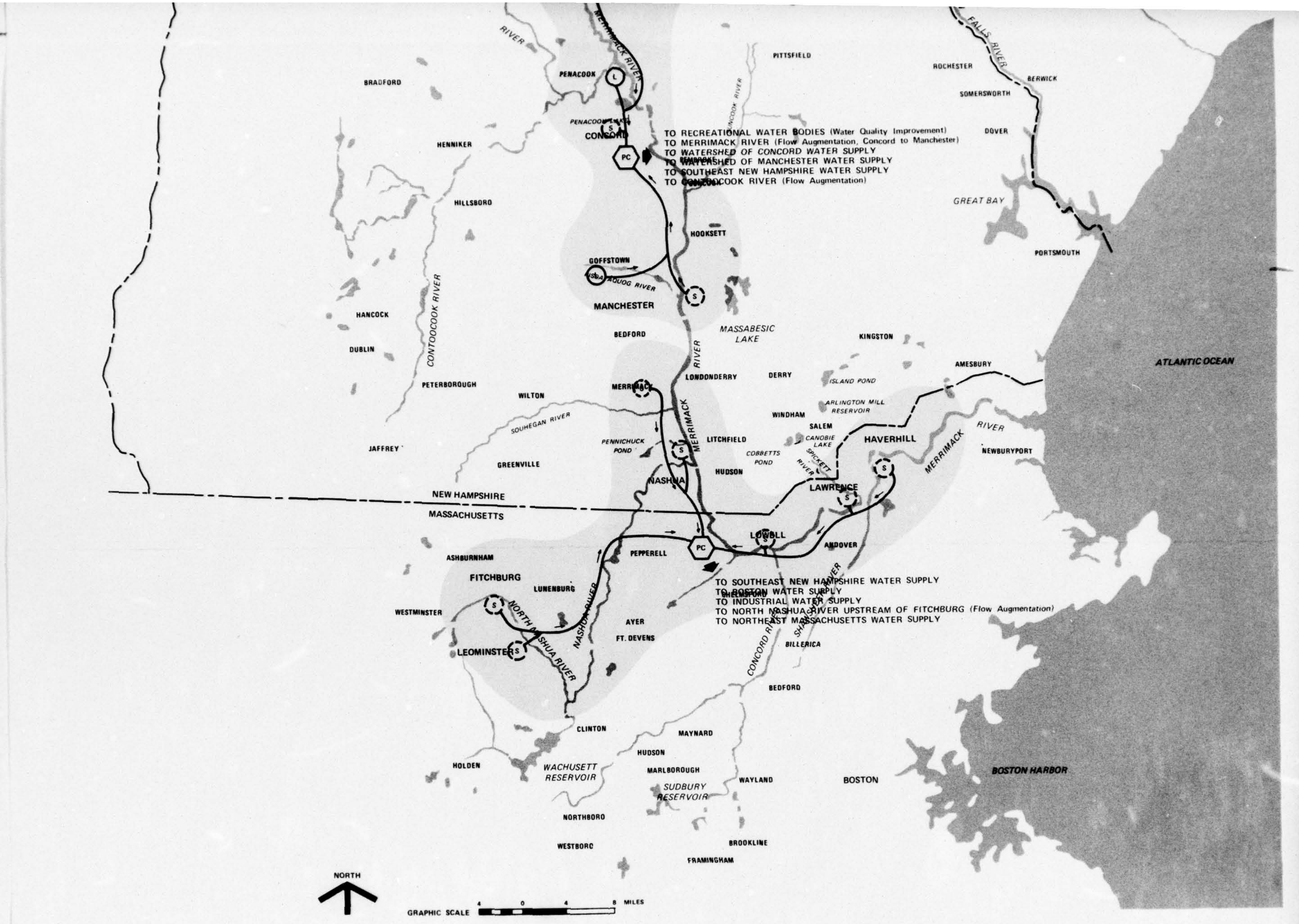
MERRIMACK WASTEWATER MANAGEMENT STUDY
ESTIMATED ANNUAL OPERATING COSTS*

Scheme No. 2 Partially Decentralized, Water Oriented Systems

	Study Area				
Item	L-L-H & Nashua	Fitch.-Leom.	Manchester-Concord	Winn. River	Total
1. Annual Operating and Maint., & Power Costs	$25.9	$ 9.0	$10.0	$ 3.3	$48.2
2. Annual Interest and Amortization on Capital Costs (5⅜%)	—	—	—	—	—
a. Pipe in place, tunnels Chambers (based on 50 yr. life)	13.8	4.2	6.1	.9	25.0
b. Plants, Pump Stations, Lagoons, etc. (based on 30 yr. life)	11.9	4.9	3.4	1.0	21.2
c. Irrigation Systems (based on 20 yr. life)	—	—	—	—	—
d. Estimated Annual Amortization Cost	25.8	9.1	9.5	1.9	46.2
e. Total Estimated Annual Operating, Maintenance & Amortization Cost	51.7	18.1	19.5	5.2	94.4
f. Say	$51.7	$18.0	$19.5	$ 5.5	$95.0

* Figures are in Millions of Dollars

SCHEME NO. 3 – CENTRALIZED, WATER ORIENTED SYSTEM
LEGEND
REGIONAL WASTEWATER TREATMENT FACILITY
PC – Physical-Chemical Treatment
SURFACE LAGOON (Temporary Storage for Combined Sewage)
UNDERGROUND TUNNEL OR CHAMBER (Temporary Storage for Combined Sewage)
NOTE
Selection of one or more water uses shown is optional.
MT. WASHINGTON
LINCOLN
PEMIGEWASSET RIVER
WARREN
WENTWORTH
RUMNEY
PLYMOUTH
SQUAM LAKE
MOULTONBORO
ASHLAND
NEWFOUND LAKE
BRISTOL
NEW HAMPTON
THE WEIRS
LAKE WINNIPESAUKEE
WOLFBORO
GRAFTON
WINNISQUAM LAKE
SANBORNTON
LACONIA
DANBURY
TILTON
BELMONT
ALTON
FRANKLIN
NORTHFIELD
GILMANTOWN
NEW LONDON
BLACK WATER RIVER
MERRIMACK RIVER
PITTSFIELD
BRADFORD
PENACOOK
CONCORD
HENNIKER
HILLSBORO
HOOKSETT
NEW HAMPSHIRE
MAINE
SANFORD
SALMON FALLS RIVER
ROCHESTER
BERWICK
SOMERSWORTH
DOVER
GREAT BAY
TO RECREATIONAL WATER BODIES (Water Quality Improvement)
TO MERRIMACK RIVER (Flow Augmentation, Concord to Manchester)
TO WATERSHED OF CONCORD WATER SUPPLY
TO WATERSHED OF MANCHESTER WATER SUPPLY
TO SOUTHEAST NEW HAMPSHIRE WATER SUPPLY
TO CONTOOCOOK RIVER (Flow Augmentation)


ATLANTIC OCEAN
BOSTON HARBOR
TO RECREATIONAL WATER BODIES (Water Quality Improvement)
TO MERRIMACK RIVER (Flow Augmentation, Concord to Manchester)
TO WATERSHED OF CONCORD WATER SUPPLY
TO WATERSHED OF MANCHESTER WATER SUPPLY
TO SOUTHEAST NEW HAMPSHIRE WATER SUPPLY
TO CONTOOCOOK RIVER (Flow Augmentation)
TO SOUTHEAST NEW HAMPSHIRE WATER SUPPLY
TO BOSTON WATER SUPPLY
TO INDUSTRIAL WATER SUPPLY
TO NORTH NASHUA RIVER UPSTREAM OF FITCHBURG (Flow Augmentation)
TO NORTHEAST MASSACHUSETTS WATER SUPPLY
NEW HAMPSHIRE
MASSACHUSETTS
MERRIMACK RIVER
CONTOOCOOK RIVER
SOUHEGAN RIVER
NASHUA RIVER
NORTH NASHUA RIVER
CONCORD RIVER
FALLS RIVER
PENACOOK
CONCORD
BRADFORD
HENNIKER
HILLSBORO
HANCOCK
DUBLIN
PETERBOROUGH
JAFFREY
WILTON
GREENVILLE
GOFFSTOWN
MANCHESTER
HOOKSETT
BEDFORD
MASSABESIC LAKE
LONDONDERRY
DERRY
MERRIMACK
PENNICHUCK POND
LITCHFIELD
NASHUA
HUDSON
COBBETTS POND
WINDHAM
SALEM
CANOBIE LAKE
SPICKETT RIVER
ISLAND POND
ARLINGTON MILL RESERVOIR
KINGSTON
AMESBURY
HAVERHILL
LAWRENCE
NEWBURYPORT
ANDOVER
LOWELL
BILLERICA
PEPPERELL
ASHBURNHAM
FITCHBURG
LUNENBURG
WESTMINSTER
LEOMINSTER
AYER
FT. DEVENS
CLINTON
HOLDEN
WACHUSETT RESERVOIR
NORTHBORO
WESTBORO
HUDSON
MARLBOROUGH
MAYNARD
SUDBURY RESERVOIR
WAYLAND
BEDFORD
BOSTON
BROOKLINE
FRAMINGHAM
PITTSFIELD
ROCHESTER
SOMERSWORTH
BERWICK
DOVER
GREAT BAY
PORTSMOUTH
PC
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NORTH
GRAPHIC SCALE
4
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4
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MILES

2

SCHEME NO. 3: CENTRALIZED, WATER ORIENTED SYSTEM

Selection Criteria:

- Maximizes physical integration and economies of scale
- Uses alternative advanced water oriented technology
- Centralizes available reusable water
- Maximizes opportunities for regional cooperation among urban areas
- Maximizes development opportunities among urban areas along wastewater transmission routes

Design Criteria:

- Designed for municipal, industrial and stormwater volumes projected to 1990 (including a 2.6" rainfall in 6 hours)

Scheme Components:

Basic

None

Advanced

(PC) Two regional physical-chemical wastewater treatment plants with sludge incineration

(S) Ten subsurface storage chambers and five surface lagoons for (L) temporary storage of stormwater and combined sewer flow

Approximately 184 miles of underground sewage transmission pipes and tunnels

Sludge produced by advanced treatment facilities will be incinerated on-site and used as landfill

Brines will be evaporated, stored and periodically disposed of at sea

Area Systems: 2

Northern Service Region

(Manchester, Concord, Winnipesaukee)

One regional (PC) at Concord, New Hampshire — 117 MGD capacity

Five (L), one each at Laconia, Belmont, Tilton, Penacook, and Goffstown — 144 MG, 10 MG, 125 MG, 50 MG and 37 MG capacity.

Three (S), one each at Franklin, Concord, and Manchester — 47 MG, 209 MG, 227 MG capacity.

Transmission system connecting all areas to (PC) at Concord — 67 miles.

Southern Service Region

(Nashua, Fitchburg-Leominster, Lowell-Lawrence-Haverhill)

One regional (PC) west of Lowell, Massachusetts — 259 MGD capacity.

Seven (S), one each at Fitchburg, Leominster, Lowell, Lawrence, Haverhill, Nashua and Merrimack — 278 MG, 82 MG, 277 MG, 307 MG, 149 MG, 216 MG and 94 MG capacity.

Transmission system connecting all areas to (PC) at Lowell — 117 miles.

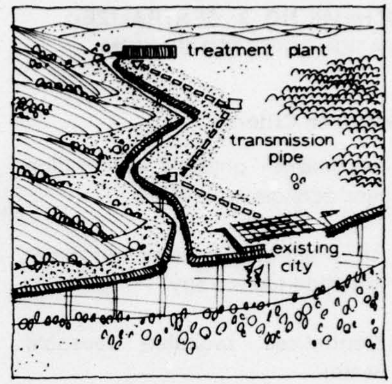
Discussion

Two physical-chemical wastewater renovation facilities would serve all six study areas; one plant for the three northern areas of Winnipesaukee, Concord, and Manchester, and another for the three southern areas of Lowell-Lawrence-Haverhill, Nashua, and Fitchburg-Leominster. Large transmission lines would funnel from the urban areas into these two locations. Routing for the lines could be determined in accordance with both inter-urban and rural development goals, seeking to promote growth in some areas and preserving the undeveloped status of other areas.

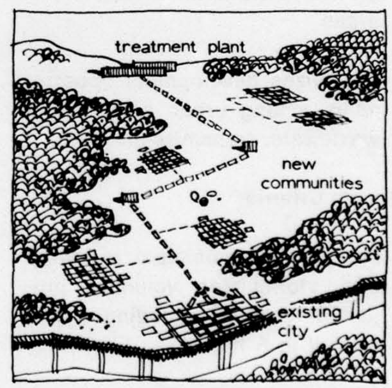
Implementation of the scheme would prove difficult due to the interregional and interstate cooperation required to participate in such a large joint venture. However, the complexity of the institutional situation is not without merit. If the cooperation necessary for implementation were achieved, the physical nature of the scheme would almost mandate a continuing unity of effort in maintaining control over wastewater renovation.

If this scheme were adopted, each of the various secondary treatment plants, either existing or planned, would have to be evaluated to determine if they should: continue to operate independently; be integrated with the system to remove some of the pollutants prior to the physical-chemical treatment process; be maintained as standby systems; or abandoned with their cost added to the cost of this scheme. In making this evaluation, due consideration would have to be given the significant economy of scale possible through such a large operation.

Another consideration attached to this scale factor is the ability to centralize large volumes of water at two locations within the basin. Reuses requiring significant quantities of water might be made quite attractive. Some of the opportunities associated with this scheme are listed on page 70, but their costs have not been included in the estimate.



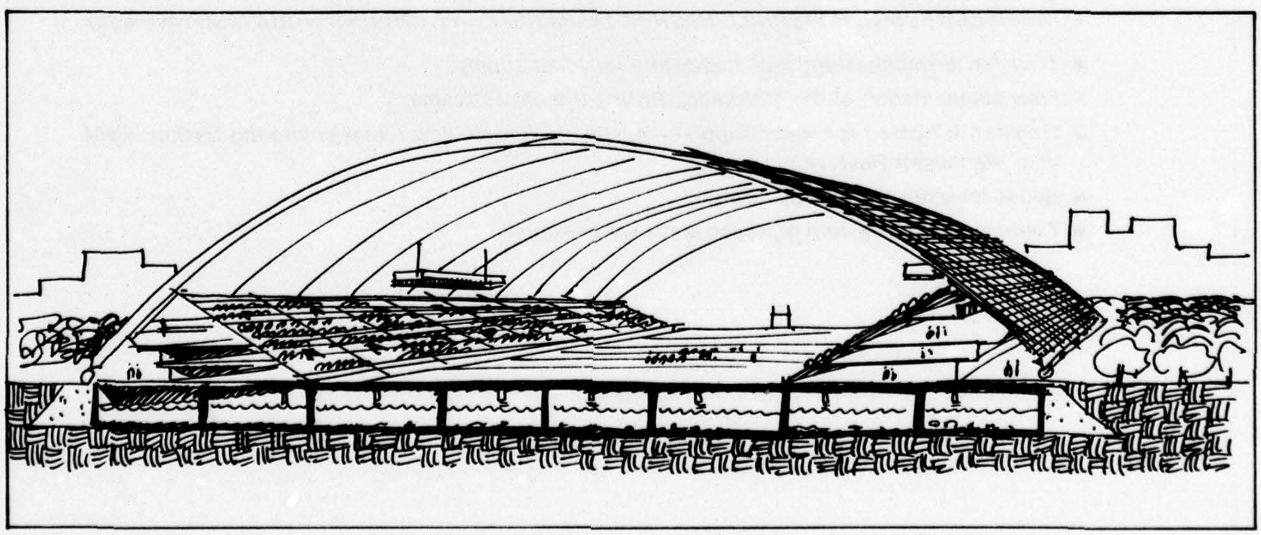
Maintaining open space



Clustering new communities

The specific impacts that are envisioned with this scheme in addition to the common ones listed previously are:

- *Creation of new suitable habitat along transmission pipes may increase the quantity of deer and other game.*
- *Diversion of flow from the Nashua River will have an unfavorable impact on this stream during low flow periods.*
- *A major disturbance will occur in the terrestrial environment at plant sites.*
- *Transmission pipes to regional facilities will significantly disrupt the landscape.*
- *The preservation of open space along transmission lines will favor the visual diversity of the landscape.*
- ***Considerable cooperation between communities and/or states will result in better decision processes.***
- ***Imaginative design of facilities can develop a large potential for multiple use.***
- ***There will be significant disruption of the scenery at plant sites during construction.***
- ***Air pollution may be increased by the incinerators.***
- ***Diversion of water outside the Basin will reduce low flows in the lower Merrimack.***



Integration of Wastewater Renovation Plant under a sports stadium

POTENTIAL USES FOR RECLAIMED WATER — SCHEME 3

NORTHERN SERVICE REGION:

WINNIPESAUKEE-CONCORD-MANCHESTER — 93 MGD (Average)

- *Return to the Concord and Manchester municipal watersheds to supplement the water supply.*
- *Flow augmentation of Merrimack River from Concord to Manchester.*
- *Containment of the reclaimed water to serve as new recreational water bodies.*
- *Diversion to the Contoocook River for flow augmentation.*
- *Transfer to southeastern New Hampshire water supply.*

SOUTHERN SERVICE REGION:

LOWELL-LAWRENCE-HAVERHILL-NASHUA-LEOMINSTER-FITCHBURG — 216 MGD (Average)

- *Transfer to southeastern New Hampshire for water supply.*
- *Flow augmentation of the Merrimack River's tributary streams.*
- *Transfer to Boston for water supply — exchange for low flow releases into the Nashua River from Wachusett Reservoir.*
- *Reuse for industrial process water.*
- *Transfer to northeastern Massachusetts water supply.*

MERRIMACK WASTEWATER MANAGEMENT STUDY
ESTIMATED COST BREAKDOWN (CAPITAL EXPENDITURES)

Scheme No. 3 Centralized, Water Oriented System

Item	L-L-H & Nashua & F-L	Manchester & Concord & Winn. River	Total
Construction			
Collection System	$ 38.0	$ 19.0	$ 57.0
Stormwater Storage	235.0	88.0	323.0
Basic Treatment			
Advanced Treatment	58.0	31.0	89.0
Sub-Total	331.0	138.0	469.0
Const. Contingencies (20%)	66.0	28.0	94.0
Sub-Total	397.0	166.0	563.0
Super. & Admin.* (8%)	32.0	13.0	45.0
Sub-Total	429.0	179.0	608.0
Engineering** (10%)	39.7	16.6	56.3
Sub-Total	468.7	195.6	664.3
Land Acquisition	2.0	1.7	3.7
Totals	470.7	197.3	668.0
Say	$471.0	$197.0	$668.0

* 8% of Construction and Contingencies
** 10% of Construction and Contingencies

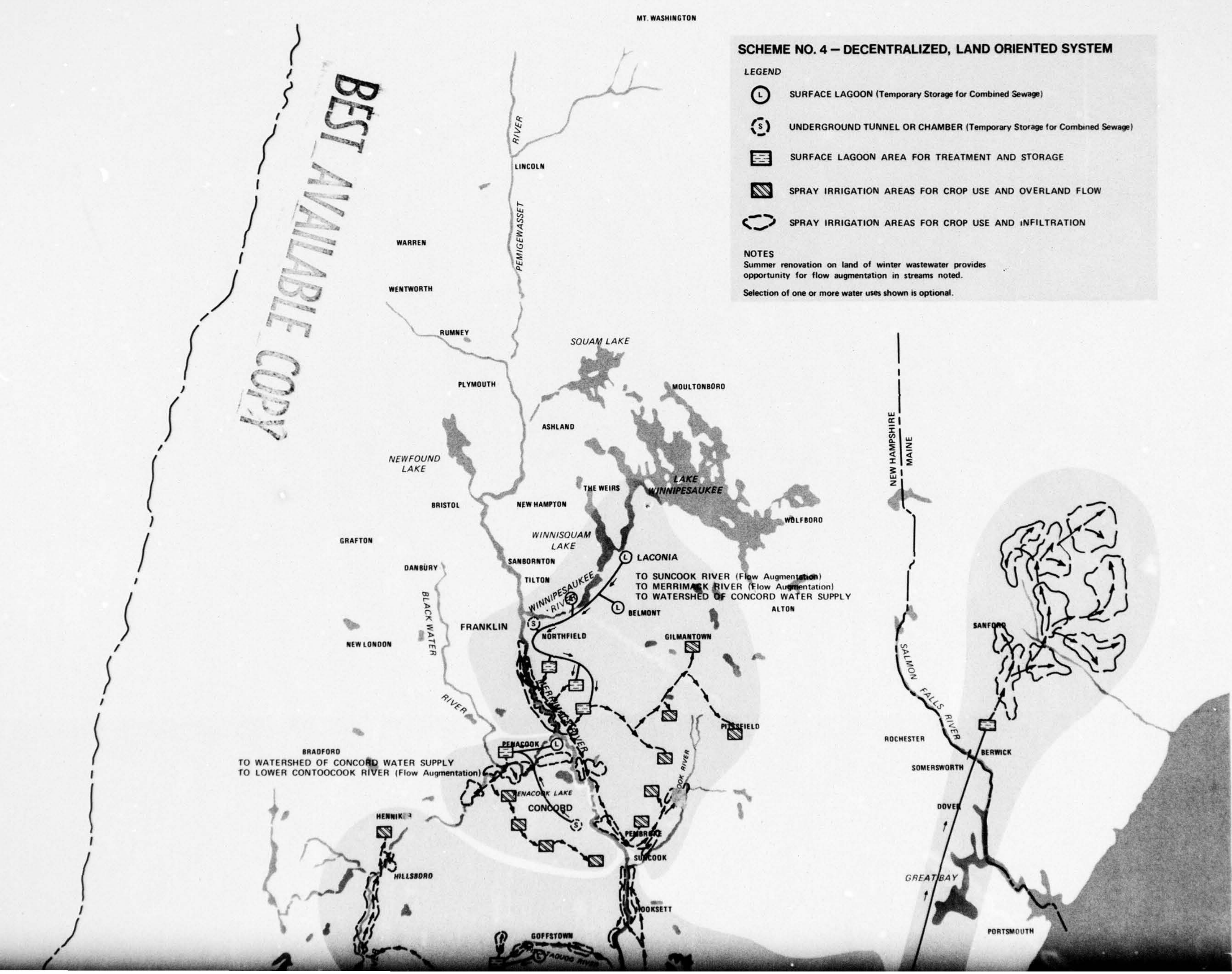
Notes:
1. Figures are in Millions of Dollars
2. Costs of schemes for reuse of renovated water are not included above
3. ENR = 1500
4. In addition to the large tunnel and pipe lines described in "Area Systems," the conveyance costs also include wastewater collection from the satellite communities in each of the six areas.

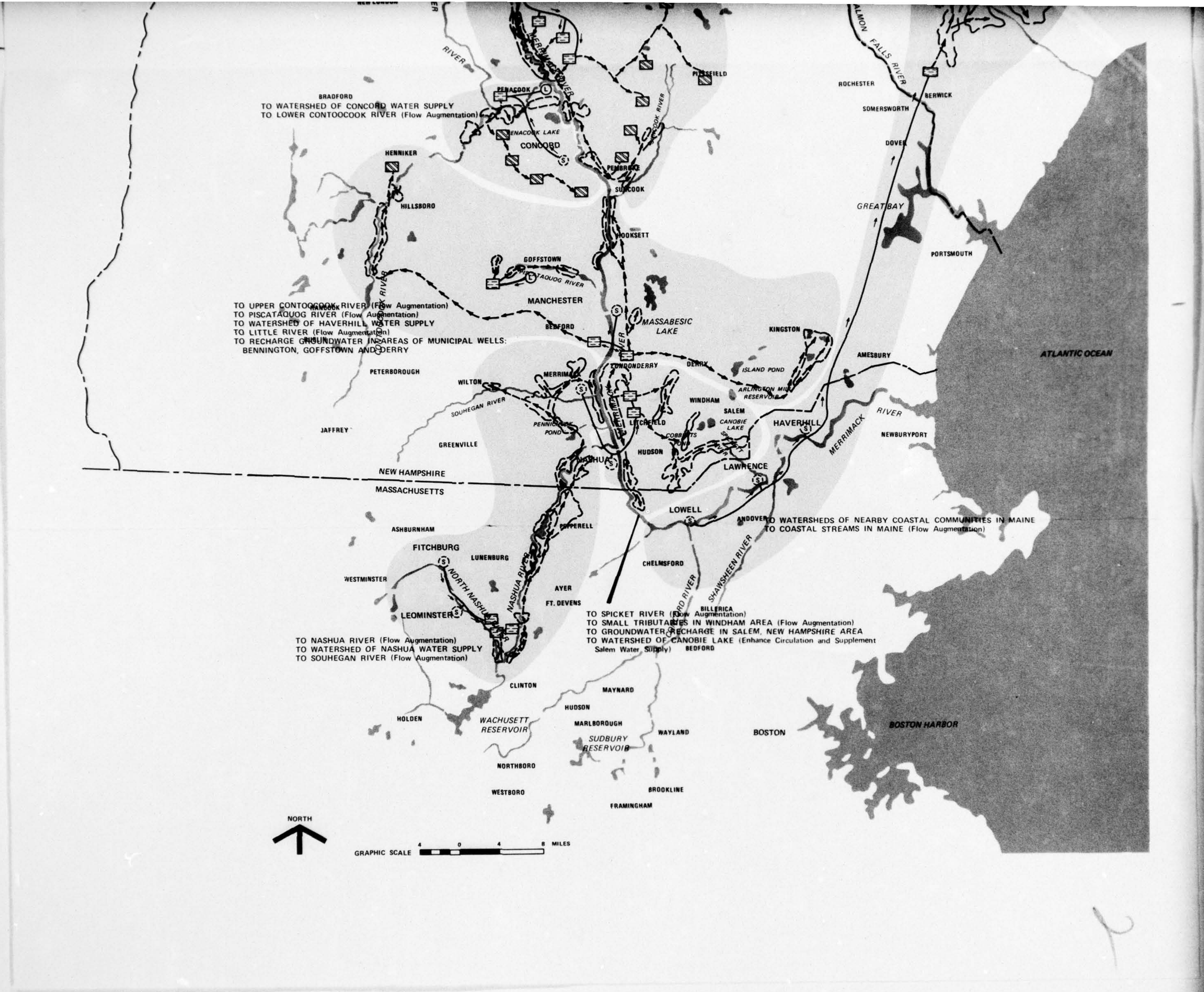
MERRIMACK WASTEWATER MANAGEMENT STUDY
ESTIMATED ANNUAL OPERATING COSTS*

Scheme No. 3 Centralized, Water Oriented System

Item	Study Areas: L-L-H & Nashua & Fitch.-Leominster	Study Areas: Manchester & Concord & Winnipesaukee River	Total
1. Annual Operating and Maint., & Power Costs	$29.2	$12.3	$41.5
2. Annual Interest and Amortization on Capital Costs (5⅜%)	—	—	—
a. Pipe in place, tunnels, & storage chambers (based on 50 yr. life)	18.4	5.6	24.0
b. Plants, pump stations, Lagoons, etc. (based on 30 yr. life)	5.8	2.7	8.5
c. Irrigation Systems	—	—	—
d. Estimated Annual Amortization Cost	24.2	8.3	32.5
e. Total Estimated Annual Operating, Maintenance & Amortization Cost	53.5	20.6	74.0
f. Say	$53.5	$20.5	$74.0

* Figures are in Millions of Dollars


SCHEME NO. 4 – DECENTRALIZED, LAND ORIENTED SYSTEM
LEGEND
SURFACE LAGOON (Temporary Storage for Combined Sewage)
UNDERGROUND TUNNEL OR CHAMBER (Temporary Storage for Combined Sewage)
SURFACE LAGOON AREA FOR TREATMENT AND STORAGE
SPRAY IRRIGATION AREAS FOR CROP USE AND OVERLAND FLOW
SPRAY IRRIGATION AREAS FOR CROP USE AND INFILTRATION
NOTES
Summer renovation on land of winter wastewater provides opportunity for flow augmentation in streams noted.
Selection of one or more water uses shown is optional.
MT. WASHINGTON
LINCOLN
PEMIGEWASSET RIVER
WARREN
WENTWORTH
RUMNEY
PLYMOUTH
SQUAM LAKE
MOULTONBORO
ASHLAND
NEWFOUND LAKE
BRISTOL
NEW HAMPTON
THE WEIRS
LAKE WINNIPESAUKEE
WOLFBORO
GRAFTON
WINNISQUAM LAKE
SANBORNTON
LACONIA
DANBURY
TILTON
TO SUNCOOK RIVER (Flow Augmentation)
TO MERRIMACK RIVER (Flow Augmentation)
TO WATERSHED OF CONCORD WATER SUPPLY
WINNIPESAUKEE RIVER
BELMONT
ALTON
BLACK WATER RIVER
FRANKLIN
NORTHFIELD
GILMANTOWN
NEW LONDON
MERRIMACK RIVER
PITTSFIELD
BRADFORD
PENACOOK
TO WATERSHED OF CONCORD WATER SUPPLY
TO LOWER CONTOOCOOK RIVER (Flow Augmentation)
PENACOOK LAKE
CONCORD
PEMBROKE
SUNCOOK
HILLSBORO
HOOKSETT
GOFFSTOWN
NEW HAMPSHIRE
MAINE
SANFORD
SALMON FALLS RIVER
ROCHESTER
BERWICK
SOMERSWORTH
DOVER
GREAT BAY
PORTSMOUTH



TO WATERSHED OF CONCORD WATER SUPPLY
TO LOWER CONTOOCOOK RIVER (Flow Augmentation)
TO UPPER CONTOOCOOK RIVER (Flow Augmentation)
TO PISCATAQUOG RIVER (Flow Augmentation)
TO WATERSHED OF HAVERHILL WATER SUPPLY
TO LITTLE RIVER (Flow Augmentation)
TO RECHARGE GROUNDWATER IN AREAS OF MUNICIPAL WELLS:
BENNINGTON, GOFFSTOWN AND DERRY
TO WATERSHEDS OF NEARBY COASTAL COMMUNITIES IN MAINE
TO COASTAL STREAMS IN MAINE (Flow Augmentation)
TO SPICKET RIVER (Flow Augmentation)
TO SMALL TRIBUTARIES IN WINDHAM AREA (Flow Augmentation)
TO GROUNDWATER RECHARGE IN SALEM, NEW HAMPSHIRE AREA
TO WATERSHED OF CANOBIE LAKE (Enhance Circulation and Supplement Salem Water Supply)
TO NASHUA RIVER (Flow Augmentation)
TO WATERSHED OF NASHUA WATER SUPPLY
TO SOUHEGAN RIVER (Flow Augmentation)
BRADFORD
PENACOOK
CONCORD
PENACOOK LAKE
PITTSFIELD
PEMBROKE
SUNCOOK
HENNIKER
HILLSBORO
HOOKSETT
GOFFSTOWN
PISCATAQUOG RIVER
MANCHESTER
BEDFORD
MASSABESIC LAKE
LONDONDERRY
DERRY
ISLAND POND
ARLINGTON MILL RESERVOIR
KINGSTON
PETERBOROUGH
WILTON
MERRIMACK
SOUHEGAN RIVER
PENNICHUCK POND
JAFFREY
GREENVILLE
LITCHFIELD
WINDHAM
SALEM
CANOBIE LAKE
HUDSON
NASHUA
LAWRENCE
HAVERHILL
NEW HAMPSHIRE
MASSACHUSETTS
LOWELL
ANDOVER
ASHBURNHAM
PEPPERELL
FITCHBURG
LUNENBURG
NORTH NASHUA RIVER
NASHUA RIVER
WESTMINSTER
AYER
FT. DEVENS
CHELMSFORD
SHAWSHEEN RIVER
BILLERICA
LEOMINSTER
BEDFORD
CLINTON
MAYNARD
HUDSON
MARLBOROUGH
HOLDEN
WACHUSETT RESERVOIR
SUDBURY RESERVOIR
WAYLAND
BOSTON
NORTHBORO
WESTBORO
BROOKLINE
FRAMINGHAM
ROCHESTER
SALMON FALLS RIVER
BERWICK
SOMERSWORTH
DOVER
GREAT BAY
PORTSMOUTH
AMESBURY
ATLANTIC OCEAN
MERRIMACK RIVER
NEWBURYPORT
BOSTON HARBOR
NORTH
GRAPHIC SCALE
4 0 4 8 MILES

SCHEME NO. 4: DECENTRALIZED, LAND ORIENTED SYSTEM

Selection Criteria:

- Utilizes wastewater nutrients in timber and crop production
- Preserves rural character of the landscape by protecting green spaces, and preventing encroachment on considerable portions of the flood plains
- Allows basin-wide augmentation of summer stream flows
- Fully utilizes land application technology
- Maximizes development opportunities among urban areas with flexible treatment lagoon and transmission line siting

Design Criteria:

- Designed for municipal, industrial, and stormwater volumes projected to 1990 (including a 2.6″ rainfall in 6 hours)

Scheme Components:

Basic

▤ 13 aerated wastewater treatment and storage lagoon areas — 13,755 acres

Advanced

▧ Approximately 8,360 acres of spray irrigation/overland flow with recapture system for renovated water

Approximately 71,650 acres of spray irrigation infiltration with recapture system for renovated water

Ⓢ Ⓛ Ten subsurface storage chambers and five surface lagoons for temporary storage of stormwater and combined sewer flow

Approximately 216 miles of underground sewage transmission pipes and tunnels

Approximately 365 miles of effluent distribution pipes and tunnels to irrigation areas

Sludge produced in the course of treatment will be anaerobically digested and applied to farm lands proximate to each area

Area Systems: 6

Winnipesaukee Area

Three ▤ south of Franklin, New Hampshire — 1,155 acres

Six ▧ at Gilmanton, Pittsfield, and Pembroke — 3,860 acres

along the Merrimack River and in the lower Suncook River Valley — 4,500 acres

One Ⓢ at Franklin — 47 MG capacity

Three Ⓛ, one each at Laconia, Tilton, and Belmont — 144 MG, 125 MG and 10 MG capacity

Transmission system connecting all areas to treatment lagoons — 31 miles

Distribution pipe carrying effluent to irrigation sites — 72 miles

Concord Area

One ▤ west of Penacook—1,060 acres

Four ▧ west and south of Concord — 4,100 acres

in the Contoocook River Valley — 4,100 acres

One Ⓢ at Concord — 209 MG capacity

One Ⓛ near Penacook — 50 MG capacity

Transmission system connecting all areas to treatment lagoons — 26 miles

Distribution pipe carrying effluent to irrigation sites — 27 miles

Manchester Area

Three ▤, one west of Goffstown and two south of Manchester — 1,950 acres

One ▧ at Henniker — 400 acres

west of Goffstown, in the Hillsboro-Henniker area, Kingston area, and along the Merri-

mack River near Hooksett — 10,-735 acres

One ⓢ near Manchester — 227 MG capacity

One Ⓛ near Goffstown — 37 MG capacity

Transmission system connecting all areas to treatment lagoons — 21 miles

Distribution pipe carrying effluent to irrigation sites — 109 miles

Nashua Area

Two ▤ at Litchfield — 1,914 acres

◌ near Litchfield and Hudson, and in the Beaver, Golden, and Porcupine Brook Valleys — 9,845 acres

Two ⓢ, one each at Nashua and Merrimack — 216 MG and 94 MG capacity

Transmission system connecting all areas to the treatment lagoons — 22 miles

Distribution pipe carrying effluent to the irrigation sites — 38 miles

Fitchburg-Leominster Area

Three ▤ east of Leominster — 2,386 acres

◌ along the Nashua River in Massachusetts and New Hampshire and in the Souhegan and Pennichuck Valleys — 13,280 acres

Two ⓢ, one each at Fitchburg and Leominster — 278 MG and 82 MG capacity

Transmission system connecting all areas to the treatment lagoons — 31 miles

Distribution pipe carrying effluent to the irrigation sites — 75 miles

Lowell-Lawrence-Haverhill Area

▤ system, in southwestern Maine — 5,290 acres

◌ area, in southwestern Maine near Sanford — 29,190 acres

Three ⓢ, one each at Lowell, Lawrence and Haverhill — 277 MG, 307 MG and 149 MG capacity

Transmission system connecting all areas to the treatment lagoons — 85 miles

Transmission and distribution pipe carrying effluent to the irrigation sites — 44 miles

Transmission line Right-of-way

Discussion

All six areas in this scheme are served by lagoon-spray irrigation systems as described in Chapter 3, the "Techniques of Water Pollution Control." The components for each of the six systems are presented in the foregoing section on "Area Systems." Because the land system operation for each of the areas is similar, the following discussion primarily contains general considerations on their operation.

The raw wastewater would be collected and transmitted to treatment lagoons by underground piping systems. There it would receive the equivalent of "secondary" treatment and be chlorinated; the effluent would meet water quality standards for irrigation water. It would then be distributed to the spray irrigation sites and applied to the land, most of which is in trees. Some, however, would be used for hay, pasture, or truck crops.

A 26-week irrigation season would be used, starting the middle of April and ending about mid-October. During the remaining 26 weeks the wastewater would be stored in large storage lagoons until the next irrigation season. Two kinds of spray irrigation would be used:

(1) Spray irrigation for crop use and overland flow, and

(2) Spray irrigation for crop use and infiltration.

New Cluster Community

The rate of application on the overland flow sites would be 1 inch per acre per week. The wastewater would be renovated by the plants, soils, and micro-organisms as it flowed over and just below the soil surface. The rate of application on the infiltration sites would be 2.5 inches per acre per week, sprayed in two applications. Because these sites consist of permeable sandy soils, groundwater management systems could be used. This would be achieved by underground tile or discharge wells, depending on the depth to the water table.

By reclaiming the renovated wastewater it could be reused to augment low stream flows, for high quality water for supplemental irrigation to areas adjacent to the Merrimack and Nashua Rivers, for improvement of stream environment, and to supplement municipal water supplies. The sludge that accumulates in the lagoons will undergo anaerobic digestion in place, then be applied to the land as a soil conditioner.

In this scheme the nutrient value of the annual wastewater flow would be beneficially used to increase crop production and forest growth. Land reserved for irrigation would help preserve the rural character of those parts of the Basin and hence preserve the scenic value. Use of river flood plains for agriculture or forest culture would be an effective tool to prevent flood plain encroachment. During the non-irrigation season this land would be available for recreational use such as small game hunting during the fall and snowmobiling in the winter.

The flexibility inherent in the physical arrangement of effluent transmission lines would allow equal flexibility in their use as land planning tools. On the other hand, institutional complexities must be expected due to the diversity of jurisdictions involved in this scheme and the number of people affected. In this scheme secondary treatment plants already in operation or about to be constructed can be substituted for treatment lagoons. Thus, the state implementation program, or any part thereof, is fully compatible with this or any other land oriented scheme.

Water for reuse, available in this scheme would be diffused over a large number of points and the volume would be reduced by about 20 percent due to the evapo-transpiration in the irrigated plots. The crops that can be grown on these plots present an opportunity for increased regional income. Some of the specific uses for the renovated water are listed on page 77. Costs for these uses, however, are not included in the estimate. It should be noted that the amount of available renovated water is given in million gallons per year; this would be available during the non-winter months.

The land disposal system offers a change in basic treatment technology and presents a large number of new and varied impacts. The following impacts are in addition to those impacts common to all alternatives and the seven schemes. Some of the specific impacts of this scheme are listed here:

- *Creation of new suitable habitat along transmission pipes may increase the quantity of deer and other game.*
- *Within the irrigation area there will be an increase in the number of insects, especially mosquitoes.*
- *A major disturbance will occur in terrestrial environment at the given lagoon facility.*
- *The addition of nitrogen and moisture will accelerate bacterial action resulting in increased reduction of forest duff (surface organic litter).*
- *Diversion of flow from the Nashua River will aggravate low flows in this stream.*
- *Pitch pine within the irrigation areas will become subject to greater degrees of windthrow damage.*
- *Lagoons will require extensive land manipulation and disruption of natural conditions.*
- *Waterfowl feeding in the lagoons may result in increased spreading of pathogens.*
- *Storage lagoons will be empty in fall and be visually unattractive.*
- *Transmission pipes to regional facilities will significantly disrupt the landscape.*
- *Land disposal sites will be looked at with pride or become a thing to hide, depending on planning, design and operation.*
- *The preservation of open space along transmission lines may greatly increase the visual diversity of the landscape.*
- *There will be considerable disruption of the scenery at plant sites during construction.*
- *Considerable cooperation between various communities and/or states will result in more effective decision processes.*
- *Imaginative design of facilities can develop a large potential for multiple use.*
- *The quantity and quality of wood products within the irrigation areas could be increased with proper management and more valuable tree species introduced.*
- *Employment during construction of the wastewater facilities will increase.*
- *Sludge disposal on land will provide a moderate source of plant nutrients and act as a soil conditioner.*
- *The utilization of wastewater as a valuable resource in crop production will be realized.*
- *Large acreages of land will remain in a semi-natural state.*

POTENTIAL USES FOR RECLAIMED WATER — SCHEME NO. 4

WINNIPESAUKEE — 8,320 MG/year (Average)

- *Flow augmentation in the Merrimack and Suncook Rivers from renovation of winter storage.*
- *Flow augmentation in small nearby streams.*
- *Transfer to watershed of Concord water supply.*

CONCORD — 8,080 MG/year (Average)

- *Flow augmentation in the lower Contoocook and Merrimack Rivers.*
- *Transfer to watershed of Concord water supply.*

MANCHESTER — 15,360 MG/year (Average)

- *Flow augmentation in the upper Contoocook and Piscataquog Rivers.*
- *Transfer of reclaimed water to the Haverhill water supply.*
- *To Little River for flow augmentation.*
- *To recharge groundwater in areas of municipal wells: Bennington and Goffstown.*

NASHUA — 13,900 MG/year (Average)

- *Transfer to Canobie Lake to enhance circulation and add to Salem, N. H. water supply.*
- *Flow augmentation of small tributaries.*
- *Flow augmentation of Spicket River.*
- *Groundwater recharge in Salem, New Hampshire.*

FITCHBURG-LEOMINSTER — 18,480 MG/year (Average)

- *Flow augmentation in the Nashua River.*
- *Augmentation in watershed of Nashua water supply.*
- *Flow augmentation in the Souhegan River.*

LOWELL-LAWRENCE-HAVERHILL — 40,640 MG/year (Average)

- *To watersheds of nearby coastal communities in Maine for water supply.*
- *Flow augmentation of coastal streams in Maine.*

MERRIMACK WASTEWATER MANAGEMENT STUDY
ESTIMATED COST BREAKDOWN (CAPITAL EXPENDITURES)

Scheme No. 4 Decentralized, Land Oriented System

Item	L-L-H	Nashua	F-L	Manchester	Concord	Winn. River	Total
Construction							
Conveyance System	$ 72.1	$ 12.5	$ 34.7	$ 33.1	$ 10.4	$ 15.3	$178.1
Stormwater Storage	122.5	51.9	60.2	44.2	35.4	15.2	829.4
Treatment Lagoons	63.5	23.0	28.6	23.4	12.7	13.9	165.2
Irrigation System	20.5	6.9	9.3	7.5	2.9	3.2	50.2
Overland Flow	—	—	—	.2	2.0	1.9	4.1
Sub-Totals	278.6	94.3	132.8	108.4	63.4	49.5	727.0
Const. Contingencies (20%)	55.7	19.0	26.6	21.7	12.8	10.0	145.8
Sub-Total	334.3	113.3	159.4	130.1	76.2	59.5	872.8
Superv. & Admin. (8%)*	29.4	9.0	12.7	10.4	6.1	4.8	72.4
Sub-Total	363.7	122.3	172.1	140.5	82.3	64.3	945.2
Engineering (10%)**	33.4	11.3	15.9	13.0	7.6	6.0	87.2
Sub-Total	397.1	133.6	188.0	153.5	89.9	70.3	1032.4
Land Acquisition	26.6	11.8	9.1	10.2	7.9	9.5	75.1
Total Est. Cost	423.7	154.4	197.1	163.7	97.8	79.8	1107.5
Say	$424.0	$145.0	$197.0	$164.0	$ 98.0	$ 80.0	$1108.0

* 8% of Construction and Contingencies
** 10% of Construction and Contingencies

Notes:
1. Figures are in Millions of Dollars
2. Costs of schemes for reuse of renovated water are not included above
3. ENR = 1500
4. In addition to the large tunnel and pipe lines described in "Area Systems," the conveyance costs also include wastewater collection from the satellite communities in each of the six areas.

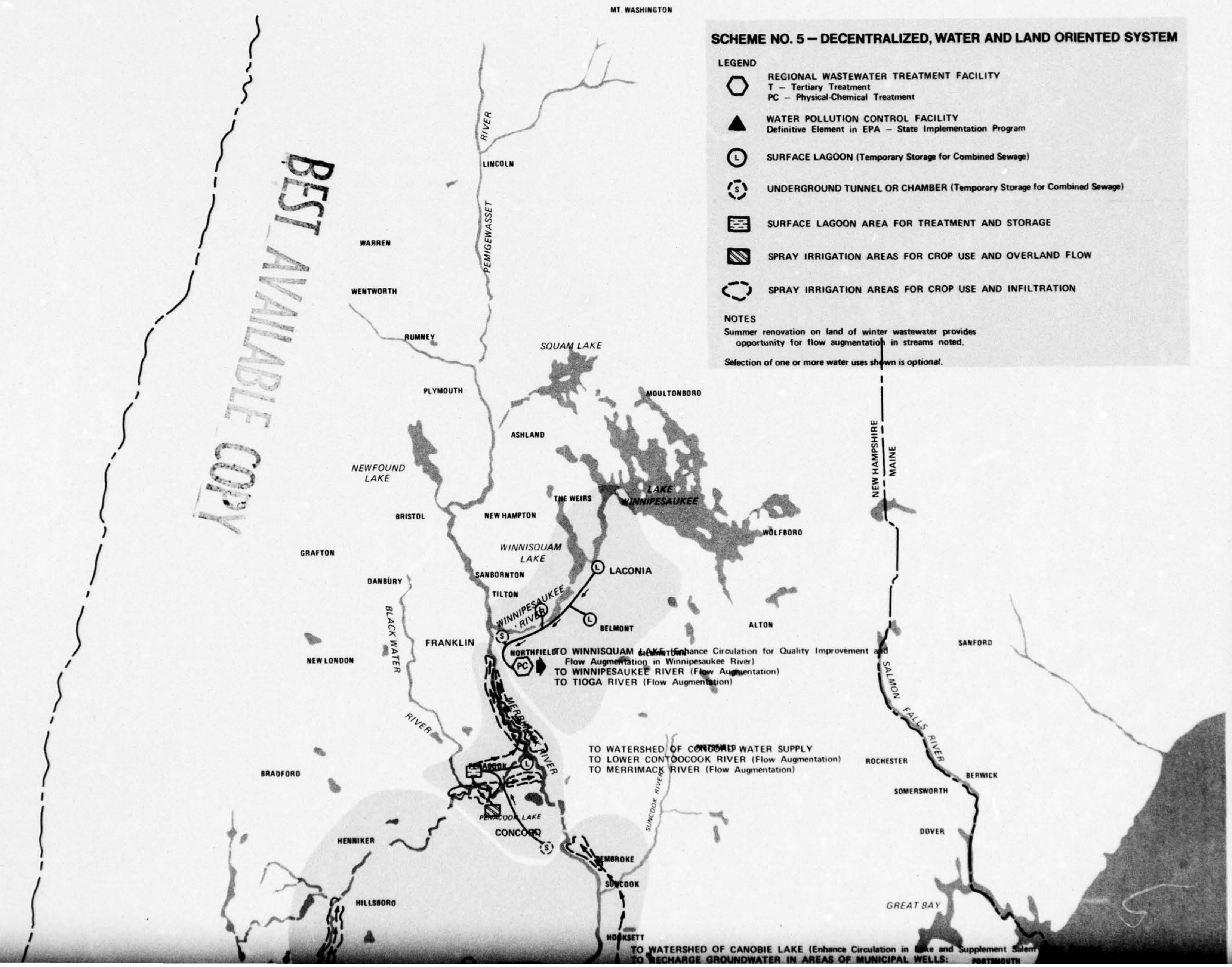
MERRIMACK WASTEWATER MANAGEMENT STUDY
ESTIMATED ANNUAL OPERATING COSTS*

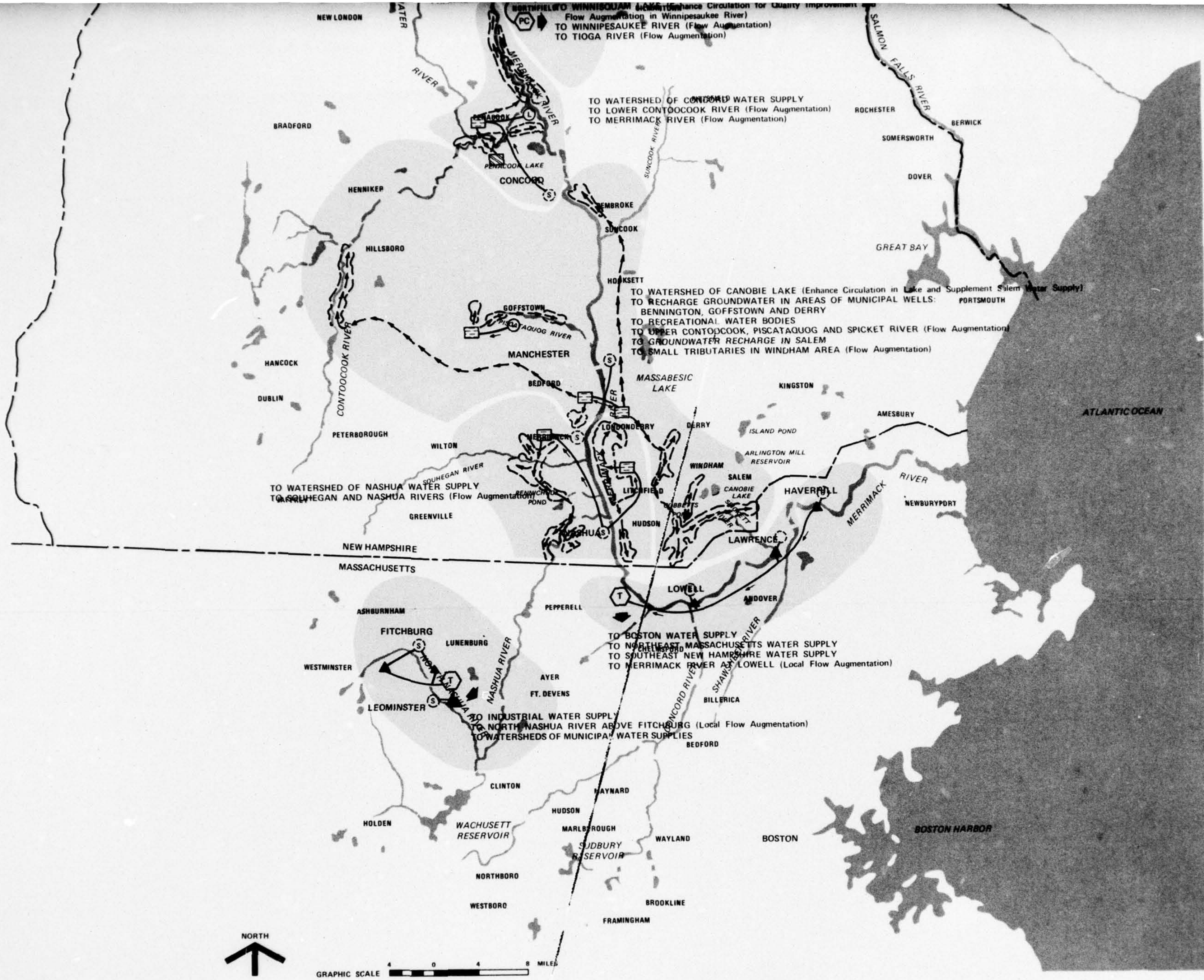
Scheme No. 4 Decentralized, Land Oriented System

Item	L-L-H	Nashua	F-L	Manchester	Concord	Winn. River	Total
1. Annual Operating Maintenance & Power Costs	$12.0	$ 4.5	$ 5.8	$ 5.4	$ 3.1	$ 3.4	$34.2
2. Annual Interest & Amortization Costs (5⅜%)	—	—	—	—	—	—	—
a. Pipe in Place, Tunnels, Chambers (based on 50 yr. life)	13.5	4.5	6.6	5.4	3.2	2.1	35.3
b. Lagoons etc. (based on 30 yr. life)	5.3	1.9	2.4	2.0	1.1	1.1	13.8
c. Irrigation Systems (based on 20 yr. life)	2.1	.7	1.0	.8	.3	.2	5.1
d. Estimated Annual Interest & Amortization Cost	20.9	7.1	10.0	8.2	4.6	3.4	54.2
e. Annual Operating, Maintenance, Interest Amortization Costs	32.9	11.6	15.8	13.6	7.7	6.8	88.4
f. Say	$33.0	$11.5	$16.0	$13.5	$ 7.5	$ 6.5	$88.0

* Figures are based on the estimated construction cost and 20% contingencies
Figures are in Millions of Dollars

Merrimack River at Lowell, Massachusetts


SCHEME NO. 5 – DECENTRALIZED, WATER AND LAND ORIENTED SYSTEM
LEGEND
REGIONAL WASTEWATER TREATMENT FACILITY
T – Tertiary Treatment
PC – Physical-Chemical Treatment
WATER POLLUTION CONTROL FACILITY
Definitive Element in EPA – State Implementation Program
SURFACE LAGOON (Temporary Storage for Combined Sewage)
UNDERGROUND TUNNEL OR CHAMBER (Temporary Storage for Combined Sewage)
SURFACE LAGOON AREA FOR TREATMENT AND STORAGE
SPRAY IRRIGATION AREAS FOR CROP USE AND OVERLAND FLOW
SPRAY IRRIGATION AREAS FOR CROP USE AND INFILTRATION
NOTES
Summer renovation on land of winter wastewater provides opportunity for flow augmentation in streams noted.
Selection of one or more water uses shown is optional.
MT. WASHINGTON
LINCOLN
PEMIGEWASSET RIVER
WARREN
WENTWORTH
RUMNEY
PLYMOUTH
SQUAM LAKE
MOULTONBORO
ASHLAND
NEWFOUND LAKE
BRISTOL
NEW HAMPTON
THE WEIRS
LAKE WINNIPESAUKEE
WOLFBORO
GRAFTON
WINNISQUAM LAKE
SANBORNTON
LACONIA
DANBURY
TILTON
WINNIPESAUKEE RIVER
BLACK WATER RIVER
BELMONT
ALTON
FRANKLIN
NORTHFIELD
NEW LONDON
TO WINNISQUAM LAKE (Enhance Circulation for Quality Improvement and Flow Augmentation in Winnipesaukee River)
TO WINNIPESAUKEE RIVER (Flow Augmentation)
TO TIOGA RIVER (Flow Augmentation)
NEW HAMPSHIRE
MAINE
SANFORD
SALMON FALLS RIVER
MERRIMACK RIVER
TO WATERSHED OF CONCORD WATER SUPPLY
TO LOWER CONTOOCOOK RIVER (Flow Augmentation)
TO MERRIMACK RIVER (Flow Augmentation)
BRADFORD
ROCHESTER
BERWICK
SOMERSWORTH
PENACOOK LAKE
CONCORD
SUNCOOK RIVER
HENNIKER
DOVER
PEMBROKE
SUNCOOK
HILLSBORO
GREAT BAY
HOOKSETT
TO WATERSHED OF CANOBIE LAKE (Enhance Circulation in Lake and Supplement Salem
TO RECHARGE GROUNDWATER IN AREAS OF MUNICIPAL WELLS:
PORTSMOUTH


TO WINNISQUAM (Enhance Circulation for Quality Improvement and Flow Augmentation in Winnipesaukee River)
TO WINNIPESAUKEE RIVER (Flow Augmentation)
TO TIOGA RIVER (Flow Augmentation)
TO WATERSHED OF CONCORD WATER SUPPLY
TO LOWER CONTOOCOOK RIVER (Flow Augmentation)
TO MERRIMACK RIVER (Flow Augmentation)
TO WATERSHED OF CANOBIE LAKE (Enhance Circulation in Lake and Supplement Salem Water Supply)
TO RECHARGE GROUNDWATER IN AREAS OF MUNICIPAL WELLS:
BENNINGTON, GOFFSTOWN AND DERRY
TO RECREATIONAL WATER BODIES
TO UPPER CONTOOCOOK, PISCATAQUOG AND SPICKET RIVER (Flow Augmentation)
TO GROUNDWATER RECHARGE IN SALEM
TO SMALL TRIBUTARIES IN WINDHAM AREA (Flow Augmentation)
TO WATERSHED OF NASHUA WATER SUPPLY
TO SOUHEGAN AND NASHUA RIVERS (Flow Augmentation)
TO BOSTON WATER SUPPLY
TO NORTHEAST MASSACHUSETTS WATER SUPPLY
TO SOUTHEAST NEW HAMPSHIRE WATER SUPPLY
TO MERRIMACK RIVER AT LOWELL (Local Flow Augmentation)
TO INDUSTRIAL WATER SUPPLY
TO NORTH NASHUA RIVER ABOVE FITCHBURG (Local Flow Augmentation)
TO WATERSHEDS OF MUNICIPAL WATER SUPPLIES
NEW LONDON
BRADFORD
HENNIKER
HILLSBORO
HANCOCK
DUBLIN
PETERBOROUGH
CONTOOCOOK RIVER
CONCORD
PENACOOK LAKE
MERRIMACK RIVER
PEMBROKE
SUNCOOK
SUNCOOK RIVER
HOOKSETT
GOFFSTOWN
PISCATAQUOG RIVER
MANCHESTER
BEDFORD
MASSABESIC LAKE
LONDONDERRY
DERRY
WILTON
SOUHEGAN RIVER
GREENVILLE
LITCHFIELD
HUDSON
NASHUA
WINDHAM
SALEM
CANOBIE LAKE
ISLAND POND
ARLINGTON MILL RESERVOIR
KINGSTON
AMESBURY
HAVERHILL
LAWRENCE
ANDOVER
LOWELL
MERRIMACK RIVER
NEWBURYPORT
ROCHESTER
SOMERSWORTH
BERWICK
DOVER
SALMON FALLS RIVER
GREAT BAY
PORTSMOUTH
ATLANTIC OCEAN
NEW HAMPSHIRE
MASSACHUSETTS
ASHBURNHAM
FITCHBURG
LUNENBURG
WESTMINSTER
LEOMINSTER
NASHUA RIVER
PEPPERELL
AYER
FT. DEVENS
CONCORD RIVER
SHAWSHEEN RIVER
BILLERICA
BEDFORD
CLINTON
MAYNARD
HUDSON
MARLBOROUGH
HOLDEN
WACHUSETT RESERVOIR
SUDBURY RESERVOIR
WAYLAND
BOSTON
BOSTON HARBOR
NORTHBORO
WESTBORO
BROOKLINE
FRAMINGHAM
NORTH
GRAPHIC SCALE
4 0 4 8 MILES

SCHEME NO. 5: DECENTRALIZED, WATER AND LAND ORIENTED SYSTEM

Selection Criteria:

- Utilizes mixed land and water oriented technologies.
- Utilizes many definitive portions of the current implementation program.
- Eliminates use of land outside the Merrimack Basin.
- Partial utilization of wastewater nutrients in timber and crop production.
- Partial preservation of rural character through protection of green space and flood plains.

Design Criteria:

- Designed for municipal, industrial and stormwater volumes projected to 1990 (including a 2.6" rainfall in 6 hours)

Scheme Components:

Basic

▲ Six activated sludge wastewater treatment plants with sludge digestion and dewatering facilities

▤ Six aerated wastewater treatment and storage lagoon areas—4,924 acres

Advanced

Ⓣ Two regional tertiary wastewater treatment plants with sludge dewatering facilities

Ⓟⓒ One regional physical-chemical wastewater treatment plant with sludge digestion and dewatering facilities

▧ Approximately 1,400 acres of spray irrigation/overland flow with recapture system for renovated water

◌ Approximately 25,940 acres of spray irrigation/infiltration with recapture system for renovated water

Ⓢ Ⓛ Ten subsurface storage chambers and five surface lagoons for temporary storage of stormwater and combined sewer flow

Approximately 165 miles of underground sewage transmission pipes and tunnels

Sludges produced in the course of treatment will be anaerobically digested and applied to farm land proximate to each area

Approximately 117 miles of effluent distribution pipes to irrigation areas

Brines will be evaporated, stored, and periodically disposed of at sea

Area Systems: 6

Winnipesaukee Area

One regional Ⓟⓒ at Franklin, N.H. — 34 MGD capacity.

One Ⓢ at Franklin — 47 MG capacity.

Three Ⓛ, one each at Laconia, Belmont, and Tilton — 144 MG, 10 MG, and 125 MG capacity.

Transmission system connecting all areas to Ⓟⓒ at Franklin — 19 miles.

Concord Area

One ▤ west of Penacook—1,060 acres.

One ▧ southwest of Penacook — 1,402 acres.

◌ in the Contoocook Valley and along the Merrimack — 5,200 acres.

One Ⓢ at Concord — 209 MG capacity.

One Ⓛ near Penacook — 50 MG capacity.

Transmission system connecting all areas to treatment lagoons — 28 miles.

Distribution pipe carrying effluent to irrigation sites — 19 miles.

Manchester Area

Three ▤, one west of Goffstown and two south of Manchester — 1,950 acres.

◌ sites west of Goffstown, in the Hillsboro area, in the Beaver, Golden, and Porcupine Brook valleys and along the Merrimack River near Pembroke — 10,895 acres.

One Ⓢ near Manchester — 227 MG capacity.

One Ⓛ near Goffstown — 37 MG capacity.

Transmission system connection all areas to treatment lagoons — 19 miles.

Distribution pipe carrying effluent to irrigation sites — 74 miles.

Nashua Area

Two ▤ one at Litchfield and one in the Souhegan River Valley — 1,914 acres.

◌ sites at Litchfield, Hudson, in the Souhegan River Valley, in the Pennichuck Brook Valley, and in the Nashua Valley in New Hampshire — 9,845 acres.

Two Ⓢ, one each at Nashua and Merrimack — 216 MG and 94 MG capacity.

Transmission system connecting all areas to the treatment lagoons — 30 miles.

Distribution pipe carrying effluent to the irrigation sites — 24 miles.

Fitchburg-Leominster Area

Three ▲, two at Fitchburg and one at Leominster — 15 MGD, 32 MGD, and 7 MGD capacity.

One regional Ⓣ at Leominster — 64 MGD capacity.

Two Ⓢ, one each at Fitchburg and Leominster — 278 MG and 82 MG capacity.

Transmission system for sewage and stormwater to Ⓣ at Leominster — 21 miles.

Lowell-Lawrence-Haverhill Area

Three ▲, one each at Lowell, Lawrence, and Haverhill — 49 MG, 64 MG, and 32 MG capacity.

One regional Ⓣ at Lowell — 145 MGD capacity.

Three Ⓢ, one each at Lowell, Lawrence and Haverhill — 277 MG, 307 MG and 149 MG capacity.

Transmission system for sewage and stormwater to Ⓣ at Lowell — 48 miles.

Discussion

This scheme suggests one of the more plausible basin-wide combinations of using either a water disposal method or a land disposal method for each of the six urban areas. This scheme is developed following the same community grouping that is used in scheme 1. The Winnipesaukee River area, Fitchburg-Leominster area, and the Lowell-Lawrence-Haverhill area would treat wastewater with water oriented systems. The Concord, Manchester, and Nashua areas would use land oriented systems. Six of the secondary treatment plants which are presently included in the Massachusetts implementation schedules are used in this scheme. Other secondary treatment plants could substitute for treatment lagoons and thus could be readily incorporated into this scheme.

Architectural potential for a Wastewater Plant

Wastewater from the communities in the Winnipesaukee River area would be transmitted to a single physical-chemical plant near Franklin, the same configuration as scheme 1. The suggested alternatives for reuse of the renovated water seem to favor treatment at a central location so that the water would be available at a single source.

In the Concord area all wastewater from Penacook, Concord, Pembroke, Suncook, Hooksett, and part of Bow would be transmitted to a treatment lagoon in the Contoocook River valley. During the non-irrigation season partially treated wastewater would be held in the storage lagoons for use later. During the growing season effluent from the outlet lagoons would be disinfected by chlorination and distributed for final renovation to the irrigation areas in the Contoocook River valley and the Merrimack River valley north of Concord.

Goffstown, Manchester, and Bedford are in the next study area. Goffstown by itself would have a small land oriented system using nearby available land. Wastewater from the other two municipalities would be transmitted to two large treatment lagoon areas, both south of Manchester. Partially treated wastewater from these lagoons would be distributed to six irrigation areas — along the Merrimack River near Pembroke and Merrimack, along the upper Contoocook River near Hillsboro, and in the Beaver, Golden, and Porcupine Brook valleys north of Lowell in New Hampshire.

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THE MERRIMACK: DESIGNS FOR A CLEAN RIVER. ALTERNATIVES FOR MANA--ETC(U)
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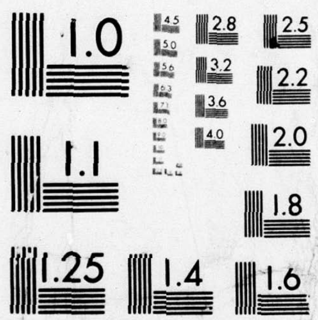
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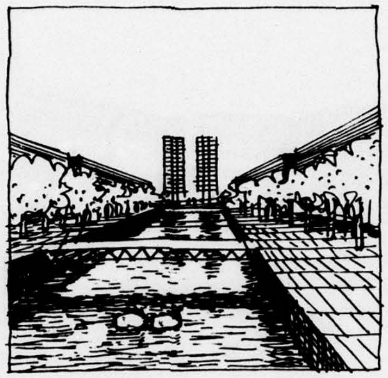
In the Nashua area, which includes Hudson and Merrimack, wastewater would be conveyed to two treatment lagoon areas. Effluent from the western lagoon area would be transmitted to irrigation sites in the Souhegan River, Pennichuck Brook, and Nashua River valleys. Irrigation sites in Litchfield and Hudson would use the effluent from the eastern lagoon area.

Lunenburg and Westminster are included in the Fitchburg-Leominster area. Wastewater flow would be divided between three activated sludge plants (one located in the western part of Fitchburg, one in eastern Fitchburg, and one in Leominster) for secondary treatment. Effluent from these plants would be transmitted to a regional tertiary facility just south of Leominster.



Redevelopment canal

Municipalities included in the Lowell-Lawrence-Haverhill area are Dracut, Chelmsford, Tewksbury, Billerica, North Andover, Andover, Methuen, and Groveland. Effluent from activated sludge plants in this area would be transmitted to one regional tertiary facility located west of Lowell.

Institutional arrangements for this scheme should not be complex. The solutions for each urban study area are physically independent of one another and there are no interstate connections. However, institutional arrangements would have to facilitate urban-rural cooperation in the New Hampshire areas using land oriented systems.

Some specific uses for the renovated water are listed on page 86, but costs for these uses are not included in the estimate. It should be noted that the amount of available renovated water in those areas with land disposal is given in million gallons per year; this amount would be available during the warm six months only.

Some of the impacts that may occur due to the implementation of this scheme are listed here:

- *Creation of new suitable habitat along transmission pipes may increase the quantity of deer and other game.*

- *Within the irrigation areas there will be an increase in the number of insects, especially mosquitoes.*

- *A major disturbance will occur in the terrestrial environment at the given treatment plant sites.*

- *Lagoons will require extensive land manipulation and disruption of natural conditions.*

- *The addition of nitrogen and moisture will accelerate bacterial action with increased reduction of forest duff (surface organic litter).*

- *Pitch pine within the irrigation areas will become subject to a greater degree of windthrow damage.*

- *Waterfowl feeding in the lagoons may result in increased spreading of pathogens.*

- *Storage lagoons will be empty in fall and be visually unattractive.*

- *Transmission pipes to regional facilities will disrupt the landscape.*

- *The preservation of open space along transmission lines may somewhat increase the visual diversity of the landscape.*

- *There will be considerable disruption of the scenery at plant sites during construction.*

- *Cooperation between various communities and/or States will result in a more effective decision process.*

- *Land disposal sites will be looked at with pride or become a thing to hide depending on planning, design and operation.*

- *The quantity and quality of wood products within the irrigation areas could be increased with proper management.*

- *Imaginative design of facilities can develop a large potential for multiple use.*

- *Employment during construction of the wastewater facilities will increase.*

- *The utilization of the nutrient value of wastewater will be realized.*

- *Considerable acreages of land will remain in a semi-natural state.*

POTENTIAL USES FOR RECLAIMED WATER — SCHEME NO. 5

WINNIPESAUKEE — 24 MGD (Average)

- *Diversion to the head of Lake Winnisquam to enhance circulation of the lake.*
- *Flow augmentation in the Tioga and Winnipesaukee Rivers.*

CONCORD-MANCHESTER-NASHUA
CONCORD — 8,080 MG/year (Average)

- *Diversion to watershed of Penacook Lake (part of Concord's water supply)*
- *Flow augmentation in the Contoocook River.*
- *Flow augmentation in the Merrimack River.*

MANCHESTER — 15,360 MG/year (Average)

- *To groundwater recharge in the area of Derry's municipal wells.*
- *To groundwater recharge in Salem, New Hampshire.*
- *Recharge groundwater in the area of Bennington's municipal wells.*
- *Diversion to two recreational water bodies; Cobbets Pond and Canobie Lake.*
- *Flow augmentation of the Spicket River in Salem, the Piscataquog River and the Merrimack River.*
- *Flow augmentation of the upper Contoocook River.*
- *Recharge groundwater in the Goffstown Municipal well area.*

NASHUA — 13,900 MG/year (Average)

- *Reclaimed water to the watershed of Pennichuck Brook to supplement Nashua's water supply.*
- *Flow augmentation in the Souhegan and Nashua Rivers.*

FITCHBURG-LEOMINSTER — 54 MG (Average)

- *Reuse in industries.*
- *Return to watersheds of the municipal water supplies.*
- *Flow augmentation in North Branch of Nashua River.*

LOWELL-LAWRENCE-HAVERHILL — 122 MGD (Average)

- *To southeastern New Hampshire water supply (relocate tertiary plant at Haverhill).*
- *To Boston water supply.*
- *To northeastern Massachusetts water supply (relocate tertiary plant at Haverhill).*
- *To Merrimack River at Lowell for local flow augmentation.*
- *To industrial water supply.*

MERRIMACK WASTEWATER MANAGEMENT STUDY
ESTIMATED COST BREAKDOWN (CAPITAL EXPENDITURES)

Scheme No. 5 Decentralized, Water and Land Oriented Systems

Item	L-L-H	Nashua	F-L	Manchester	Concord	Winn. River	Total
Construction							
Conveyance System	$ 18.0	$ 10.6	$ 2.5	$ 28.2	$ 10.0	$ 3.0	$ 72.3
Storm Water Storage	122.0	51.8	60.0	44.0	35.5	10.0	323.3
Basic Treatment	65.0	—	35.0	—	—	—	100.0
Advanced Treatment	43.0	—	22.5	—	—	13.0	78.5
Treatment Lagoons	—	23.0	—	23.4	12.7	—	59.1
Irrigation System	—	6.9	—	7.6	3.6	—	18.1
Overland Flow	—	—	—	—	.7	—	.7
Sub-Totals	248.0	92.3	120.0	103.2	62.5	26.0	652.0
Const. Contingencies (20%)	50.0	19.0	24.0	21.0	12.5	5.0	131.5
Sub-Totals	298.0	111.3	144.0	124.2	75.0	31.0	783.5
Engineering (8%)*	24.0	9.6	12.0	10.0	6.0	3.0	64.6
Sub-Totals	322.0	120.9	156.0	134.2	81.0	34.0	848.1
Engineering (10%)**	29.8	11.1	14.4	12.4	7.5	3.1	78.3
Sub-Total	351.8	132.0	170.4	146.6	88.5	37.1	926.4
Land Acquisition	.8	11.8	.4	10.2	7.9	.5	31.6
Total Estimated Costs	352.6	143.8	170.8	156.8	96.4	37.6	958.0
Say	$353.0	$144.0	$171.0	$157.0	$ 96.0	$37.0	$958.0

* 8% of Construction and Contingencies
** 10% of Construction and Contingencies

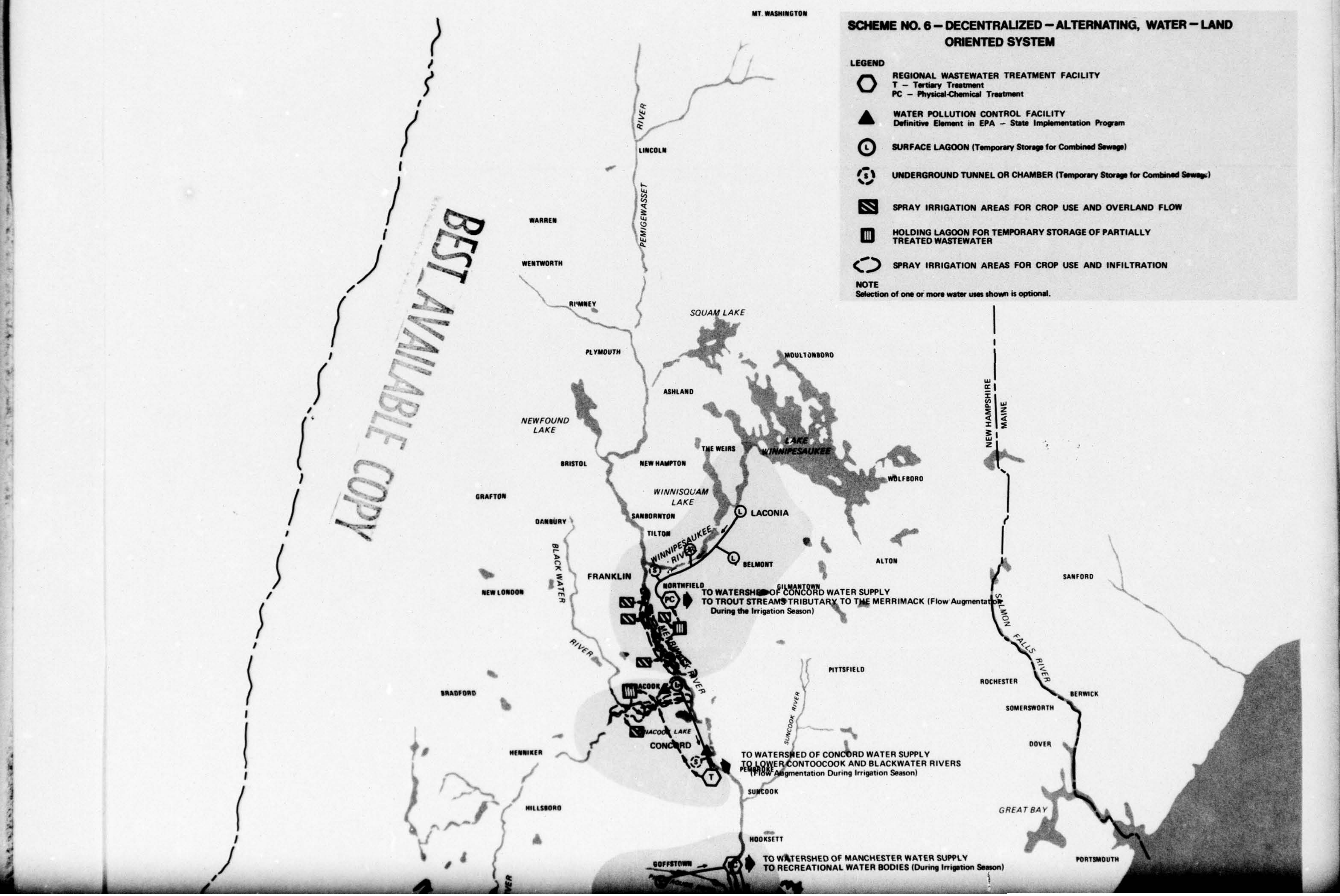
Notes:
1. Figures are in Millions of Dollars
2. Costs of schemes for reuse of renovated water are not included above
3. ENR = 1500
4. In addition to the large tunnel and pipe lines described in "Area Systems," the conveyance costs also include wastewater collection from the satellite communities in each of the six areas.

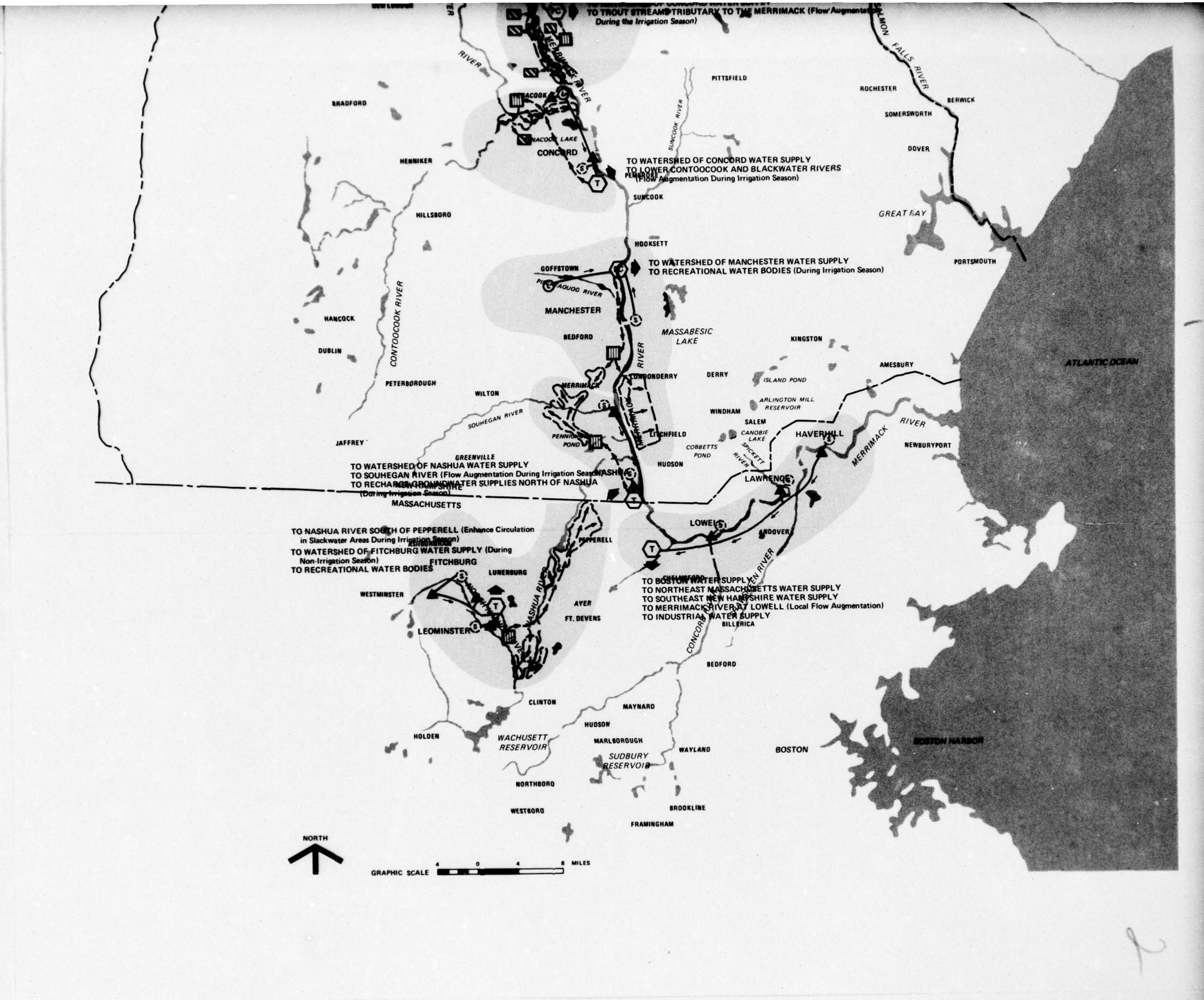
MERRIMACK WASTEWATER MANAGEMENT STUDY
ESTIMATED ANNUAL OPERATING COSTS*

Scheme No. 5 Decentralized, Water and Land Oriented Systems

Item	L-L-H	Nashua	F-L	Manchester	Concord	Winn. River	Total
1. Annual Operating, Maint., & Power Costs	$19.5	$ 4.7	$ 9.0	$ 5.4	$ 3.4	$ 3.3	$45.3
2. Annual Interest and Amortization on Capital Costs (5⅝%)							
a. Pipe in place, tunnels, chambers (based on 50 year life)	9.4	4.3	4.2	5.0	3.2	.9	27.0
b. Plants, Pump Stations, Lagoons (based on 30 yr. life)	9.5	1.9	4.9	2.0	1.0	1.0	20.3
c. Irrigation Systems (based on 20 yr. life)	—	.7	—	.8	.4	—	1.9
d. Estimated Annual Int. & Amort. Cost	18.9	6.9	9.1	7.8	4.6	1.9	49.2
e. Total Estimated Annual Operating, Maintenance & Amortization	38.4	11.6	18.1	13.2	8.0	5.2	94.5
f. Say	$38.5	$11.5	$18.0	$13.0	$ 8.0	$ 5.0	$94.0

* Figures are based on the estimated construction cost and 20% contingencies
Figures are in Millions of Dollars


SCHEME NO. 6 – DECENTRALIZED – ALTERNATING, WATER – LAND ORIENTED SYSTEM
LEGEND
REGIONAL WASTEWATER TREATMENT FACILITY
T – Tertiary Treatment
PC – Physical-Chemical Treatment
WATER POLLUTION CONTROL FACILITY
Definitive Element in EPA – State Implementation Program
SURFACE LAGOON (Temporary Storage for Combined Sewage)
UNDERGROUND TUNNEL OR CHAMBER (Temporary Storage for Combined Sewage)
SPRAY IRRIGATION AREAS FOR CROP USE AND OVERLAND FLOW
HOLDING LAGOON FOR TEMPORARY STORAGE OF PARTIALLY TREATED WASTEWATER
SPRAY IRRIGATION AREAS FOR CROP USE AND INFILTRATION
NOTE
Selection of one or more water uses shown is optional.
MT. WASHINGTON
LINCOLN
PEMIGEWASSET RIVER
WARREN
WENTWORTH
RUMNEY
PLYMOUTH
SQUAM LAKE
MOULTONBORO
ASHLAND
NEWFOUND LAKE
BRISTOL
THE WEIRS
NEW HAMPTON
LAKE WINNIPESAUKEE
WOLFBORO
NEW HAMPSHIRE
MAINE
GRAFTON
WINNISQUAM LAKE
LACONIA
DANBURY
SANBORNTON
TILTON
WINNIPESAUKEE RIVER
BELMONT
ALTON
SANFORD
FRANKLIN
NORTHFIELD
GILMANTOWN
NEW LONDON
BLACK WATER RIVER
TO WATERSHED OF CONCORD WATER SUPPLY
TO TROUT STREAMS TRIBUTARY TO THE MERRIMACK (Flow Augmentation During the Irrigation Season)
MERRIMACK RIVER
PITTSFIELD
SUNCOOK RIVER
SALMON FALLS RIVER
ROCHESTER
BERWICK
BRADFORD
SOMERSWORTH
CONCORD
DOVER
HENNIKER
TO WATERSHED OF CONCORD WATER SUPPLY
TO LOWER CONTOOCOOK AND BLACKWATER RIVERS (Flow Augmentation During Irrigation Season)
PEMBROKE
SUNCOOK
HILLSBORO
GREAT BAY
HOOKSETT
TO WATERSHED OF MANCHESTER WATER SUPPLY
TO RECREATIONAL WATER BODIES (During Irrigation Season)
GOFFSTOWN
PORTSMOUTH


TO TROUT STREAMS TRIBUTARY TO THE MERRIMACK (Flow Augmentation
During the Irrigation Season)
TO WATERSHED OF CONCORD WATER SUPPLY
TO LOWER CONTOOCOOK AND BLACKWATER RIVERS
(Flow Augmentation During Irrigation Season)
TO WATERSHED OF MANCHESTER WATER SUPPLY
TO RECREATIONAL WATER BODIES (During Irrigation Season)
TO WATERSHED OF NASHUA WATER SUPPLY
TO SOUHEGAN RIVER (Flow Augmentation During Irrigation Season)
TO RECHARGE GROUNDWATER SUPPLIES NORTH OF NASHUA
(During Irrigation Season)
TO NASHUA RIVER SOUTH OF PEPPERELL (Enhance Circulation
in Slackwater Areas During Irrigation Season)
TO WATERSHED OF FITCHBURG WATER SUPPLY (During
Non-Irrigation Season)
TO RECREATIONAL WATER BODIES
TO BOSTON WATER SUPPLY
TO NORTHEAST MASSACHUSETTS WATER SUPPLY
TO SOUTHEAST NEW HAMPSHIRE WATER SUPPLY
TO MERRIMACK RIVER AT LOWELL (Local Flow Augmentation)
TO INDUSTRIAL WATER SUPPLY
SALMON FALLS RIVER
PITTSFIELD
ROCHESTER
BERWICK
SOMERSWORTH
DOVER
BRADFORD
HENNIKER
CONCORD
SUNCOOK RIVER
SUNCOOK
HILLSBORO
GREAT BAY
PORTSMOUTH
HOOKSETT
GOFFSTOWN
PISCATAQUOG RIVER
MANCHESTER
HANCOCK
CONTOOCOOK RIVER
DUBLIN
BEDFORD
MASSABESIC LAKE
KINGSTON
RIVER
PETERBOROUGH
MERRIMACK
LONDONDERRY
DERRY
ISLAND POND
AMESBURY
ATLANTIC OCEAN
WILTON
ARLINGTON MILL RESERVOIR
WINDHAM
SALEM
SOUHEGAN RIVER
CANOBIE LAKE
HAVERHILL
MERRIMACK
RIVER
JAFFREY
PENNICHUCK POND
LITCHFIELD
COBBETTS POND
SPICKETT RIVER
NEWBURYPORT
GREENVILLE
NASHUA
HUDSON
LAWRENCE
MASSACHUSETTS
LOWELL
PEPPERELL
ANDOVER
FITCHBURG
LUNENBURG
WESTMINSTER
NASHUA RIVER
AYER
FT. DEVENS
CONCORD RIVER
LEOMINSTER
BILLERICA
BEDFORD
CLINTON
MAYNARD
HOLDEN
WACHUSETT RESERVOIR
HUDSON
MARLBOROUGH
SUDBURY RESERVOIR
WAYLAND
BOSTON
BOSTON HARBOR
NORTHBORO
WESTBORO
BROOKLINE
FRAMINGHAM
NORTH
GRAPHIC SCALE
4 0 4 8 MILES

2

SCHEME NO. 6: DECENTRALIZED, ALTERNATING WATER LAND ORIENTED SYSTEM

Selection Criteria:

- Utilizes mixed water-land oriented technologies
- Substitutes treatment plants from the definitive implementation program for treatment lagoons
- Minimizes land requirements
- Helps preserve rural character by protecting green space and preventing encroachment on considerable portions of the floor plain
- Utilizes a portion of the nutrients in wastewater on timber and crop land
- Improves treatment reliability through backup systems.

Design Criteria:

- Designed for municipal, industrial, and stormwater volumes projected for 1990 (including a 2.6" rainfall in 6 hours)

Scheme Components:

Basic

▲ Ten activated sludge wastewater treatment plants with sludge digestion and dewatering facilities

Advanced

Ⓣ Four regional tertiary wastewater treatment plants with sludge dewatering facilities

(PC) Two regional physical-chemical wastewater treatment plants with sludge digestion and dewatering facilities

▧ Approximately 2,900 acres of spray irrigation/overland flow with recapture system for renovated water

◌ Approximately 21,720 acres of spray irrigation/infiltration with a recapture system for renovated water

Ⓢ Ⓛ Ten subsurface storage chambers and five surface lagoons for temporary storage of stormwater and combined sewer flow

▥ Five surface holding lagoons for temporary storage of partially treated wastewater — 630 acres

Approximately 129 miles of underground sewage transmission pipes and tunnels

Approximately 88 miles of effluent distribution pipes to irrigation areas.

Sludge produced in the course of treatment will be anaerobically digested and applied to farm lands proximate to each area

Brines will be evaporated, stored, and periodically disposed of at sea.

Area Systems: 6

Winnipesaukee Area:

One regional (PC) at Franklin, New Hampshire — 34 MGD Capacity. Four ▧ within 2 miles of the Merrimack River — 1,500 acres.

◌ along both sides of the Merrimack River between Franklin and Concord — 2,600 acres.

One Ⓢ at Franklin — 47 MG capacity.

Three Ⓛ one each at Laconia, Belmont and Tilton — 144 MG, 10 MG, and 125 MG capacity.

Transmission system connecting all areas to (PC) at Franklin — 19 miles.

Distribution pipe carrying effluent to irrigation sites — 15 miles.

One ▥ for temporary storage of partially treated wastewater — 100 acres

Concord Area

Two ▲ , one each at Concord and Penacook — 25 MGD and 6 MGD capacity.

One regional Ⓣ at Concord — 31 MGD capacity.

One ▧ southwest of Penacook — 1,400 acres.

◌ in the Contoocook Valley — 2,500 acres.

One Ⓛ at Penacook — 50 MG capacity.

One Ⓢ at Concord — 209 MG capacity.

One ▥ for temporary storage of partially treated wastewater — 90 acres.

Transmission system connecting all areas to Ⓣ at Concord — 15 miles.

Distribution pipes carrying effluent to irrigation sites — 18 miles.

Manchester Area

One (PC) at Manchester — 52 MGD capacity.

◌ south of Manchester west of the Merrimack and near Litchfield and Londonderry — 5,250 acres.

One Ⓢ at Manchester — 227 MG capacity.

One Ⓛ near Goffstown — 37 MG capacity.

One ▥ for the temporary storage of partially treated wastewater — 135 acres.

Transmission system for sewage and stormwater connecting all areas to (PC) at Manchester — 10 miles.

Distribution pipe carrying effluent to the irrigation sites — 19 miles.

Nashua Area

Two ▲, one each at Nashua and Merrimack — 36 MGD and 14 MGD capacity.

One regional Ⓣ at Nashua — 50 MGD capacity.

◌ in the Pennichuck and Souhegan Valley — 4,900.

Two Ⓢ, one each at Nashua and Merrimack — 216 MG and 94 MG capacity.

One ▥ for temporary storage of partially treated wastewater — 135 acres.

Transmission systems for sewage and stormwater connecting all areas to Ⓣ at Nashua — 16 miles.

Distribution pipe carrying effluent to irrigation site — 9 miles.

Fitchburg-Leominster Area

Three ▲, two at Fitchburg and one at Leominster — 15 MGD, 32 MGD and 17 MGD capacity.

One regional Ⓣ at Leominster — 64 MGD capacity.

◌ along the North Nashua and Nashua Rivers in Massachusetts — 6,470 acres.

Two Ⓢ, one each at Fitchburg and Leominster — 278 MG and 82 MG capacity.

One ▥ for temporary storage of partially treated wastewater — 170 acres.

Distribution pipes carrying effluent to the irrigation site — 27 miles.

Transmission system for sewage and stormwater to regional at Leominster — 21 miles.

Lowell-Lawrence-Haverhill Area

Three ▲, one each at Lowell, Lawrence and Haverhill — 49 MGD, 64 MGD and 32 MGD capacity.

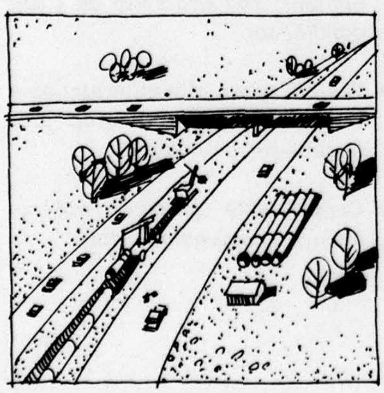
One Ⓣ west of Lowell — 145 MGD capacity.

Three Ⓢ, one each at Lowell, Lawrence and Haverhill — 277 MG 307 MG and 149 MG capacity.

Transmission system for sewage and stormwater to Ⓣ at Haverhill or Lowell — 48 miles.

Discussion

This scheme investigates another possibility of combining water and land treatment methods. Completely renovated wastewater from biological-tertiary or physical-chemical advanced wastewater treatment facilities would be discharged to water bodies during the winter months. From mid-April or early May through late September, partially renovated wastewater from the initial treatment steps in the same plants (biological oxidation or coagulation) would be disinfected by chlorination prior to land application by spray irrigation for final renovation. Renovated water from the regional tertiary plant serving the Lowell-Lawrence-Haverhill area would be discharged to a water body or diverted for use elsewhere during the whole year. The type and location of secondary treatment plants which are presently included in the EPA-State implementation program and the advanced treatment facilities suggested in scheme 1 are all compatible with this scheme.



Transmission line construction

The four New Hampshire urban areas are treated separately under this scheme; each has sufficient land available for irrigation. Enough land is available in Massachusetts east of the Fitchburg-Leominster area for effluent from that proposed regional tertiary plant. Most of the land suitable for irrigation of effluent from the proposed regional tertiary plant serving Lowell, Lawrence, and Haverhill is in New Hampshire. Because this scheme would not necessarily require any other interstate planning or control, it is considered preferable in this scheme not to use New Hampshire land for summer irrigation of partially treated wastewater from Lowell, Lawrence and Haverhill. Instead, wastewater would be treated year round at the tertiary plant.

With Lowell, Lawrence, and Haverhill following a water oriented plan, land suitable for irrigation in adjacent parts of southern New Hampshire might then be available for further needs (after 1990) of the Nashua and Manchester areas, or such land could be reserved for management of wastewater from the rapidly growing smaller communities in the area.

This scheme has several advantages over the previous schemes. Because renovated wastewater under this plan is discharged to water bodies during the winter, large storage lagoons required for Scheme 4 and for three areas in Scheme 5 are not needed. Aerated lagoons and settling lagoons are not required because the initial treatment would occur in either activated sludge plants or in coagulation units. Short term holding lagoons would be used in place of outlet lagoons to provide some storage.

Flow Augmentation Outfall

This scheme tends to combine the advantages of Schemes 1 and 4. The definitive portion of the existing EPA-State implementation plan are all used in this scheme with the advantages of momentum and institutional simplicity that this implies. This is coupled with the range of opportunities inherent in the land oriented scheme. In addition, this scheme with its dual system and its short term storage lagoons provides

an extremely reliable system, a fact that might be very important if the reclaimed water is used in a municipal water supply. Some of the specific opportunities for the use of the renovated water are shown on the next page. The cost associated with these uses, however, is not included in the estimate.

Some of the impacts that can be expected with this scheme are listed here:

- *Creation of new suitable habitat along transmission pipes may increase the quantity of deer and other game.*
- *Within the irrigation area there will be an increase in the number of insects, especially mosquitoes.*
- *A major disturbance will occur in the terrestrial environment at the given treatment plant site.*
- *Lagoons will require extensive land manipulation and disruption of natural conditions.*
- *Pitch pine within the irrigation areas will become subject to a greater degree of windthrow damage.*
- *The addition of nitrogen and moisture will accelerate bacterial action with increased reduction of forest duff (surface organic litter).*
- *Transmission pipes to regional facilities will significantly disrupt the landscape.*
- *Land disposal sites will be looked at with pride or become a thing to hide, depending on planning, design and operation.*
- *The preservation of open space along transmission lines may moderately increase the visual diversity of the landscape.*
- *There will be significant disruption of the scenery at plant sites during construction.*
- *Cooperation between various communities and/or states will result in a more effective decision process.*
- *Imaginative design of facilities can develop a large potential for multiple use.*
- *With proper management more valuable tree species could be encouraged at land disposal sites.*
- *Employment during construction of the wastewater facilities will increase.*
- *Sludge disposal on land will provide a moderate source of plant nutrients and also serve as a soil conditioner.*
- *The utilization of wastewater as a valuable resource in crop production will be realized.*
- *Considerable acreages will remain in a semi-natural state.*

POTENTIAL USES FOR RECLAIMED WATER — SCHEME NO. 6

WINNIPESAUKEE — 24 MGD (MGD irrigation season) (Average)

- *Return to watershed of Concord water supply.*
- *Flow augmentation in trout streams tributary to Merrimack River during irrigation season (Allen Brook, Stirrup Iron Brook, and Cold Brook)*

CONCORD — 24 MGD (22 MGD irrigation season) (Average)

- *Return to watershed of Penacook Lake for supplementation of the water supply.*
- *Flow augmentation in the Contoocook and Blackwater Rivers during the irrigation season.*
- *Diversion to Turkey Pond to improve circulation and augment flow in Turkey River.*

MANCHESTER — 45 MGD (40 MGD irrigation season) (Average)

- *Return to Massabesic Lake for supplementation of the water supply.*
- *Diversion to recreational water bodies; Canobie Lake, Rock Pond, Beaver Lake, Island Pond, Arlington Mill Reservoir.*
- *Return to the watershed of Nashua water supply during irrigation season.*

NASHUA — 40 MGD (32 MGD irrigation season) (Average)

- *Return to the streams in the watershed of Pennichuck Brook for supplementation of Nashua's water supply.*
- *Recharge groundwater near municipal wells north of Nashua during irrigation season.*
- *Flow augmentation in Souhegan River during irrigation season.*
- *Diversion to four recreational water bodies during irrigation season; Horseshoe Pond, Naticook Lake, Greens Pond, and Honey Pot Pond.*

FITCHBURG-LEOMINSTER — 54 MGD (43 MGD irrigation season) (Average)

- *Return to slackwater areas in Nashua River south of Pepperell to enhance circulation during irrigation season.*
- *Flow augmentation in the Nissitissit and Squannacook Rivers during irrigation season.*
- *Return to watersheds of municipal reservoirs during non-irrigation season.*
- *Diversion to two recreational water bodies to enhance circulation and recreational value, and to augment flow in tributary streams to the Nashua; Lake Shriley and Hickory Hills Lake.*

LOWELL-LAWENCE-HAVERHILL — 122 MGD (Average)

- *To southeastern New Hampshire water supply (relocate tertary plant at Haverhill).*
- *To northeastern Massachusetts water supply (relocate tertiary plant at Haverhill).*
- *To Boston water supply.*
- *Flow augmentation in the Concord River and other tributaries of the Merrimack River.*
- *To Merrimack River at Lowell for local flow augmentation.*
- *To Industrial water supply.*

MERRIMACK WASTEWATER MANAGEMENT STUDY
ESTIMATED COST BREAKDOWN (CAPITAL EXPENDITURES)

Scheme No. 6 Decentralized-Alternating, Water-Land Oriented Systems

Item	L-L-H	Nashua	F-L	Manchester	Concord	Winn. River	Total
Construction							
Conveyance System	$ 18.0	$ 7.5	$ 15.2	$ 8.5	$ 7.5	$ 8.5	$ 65.2
Stormwater Storage	122.0	51.9	60.2	44.1	35.4	10.0	323.6
Conventional Treatment	65.0	23.0	34.4	—	15.9	—	138.3
Advanced Treatment	43.0	18.3	22.4	18.6	13.0	12.7	128.0
Treatment Lagoons	—	3.4	4.2	3.4	2.3	2.5	15.8
Irrigation System	—	3.4	4.5	3.7	1.8	1.8	15.2
Overland Flow	—	—	—	—	.7	.7	1.4
Sub Totals	248.0	107.5	140.9	78.3	76.6	36.2	687.5
Constr. Contingencies (20%)	50.0	21.5	28.1	15.7	15.4	7.2	137.9
Sub Totals	298.0	129.0	169.0	94.0	92.0	43.4	825.4
Superv. & Admin.* (8%)	24.0	10.3	13.5	7.5	7.3	3.5	66.1
Sub Totals	322.0	139.3	182.5	101.5	99.3	46.9	891.5
Engineering** (10%)	29.8	12.9	16.9	9.4	9.2	4.3	82.5
Sub Totals	351.8	152.2	199.4	110.9	108.5	51.2	974.0
Land Acquisition	.8	5.1	4.8	4.8	3.2	3.2	21.9
Total Estimated Costs	352.6	157.3	204.2	115.7	111.7	54.4	995.9
Say	$353.0	$157.0	$204.0	$116.0	$112.0	$ 54.0	$996.0

* 8% of Construction and Contingencies
** 10% of Construction and Contingencies

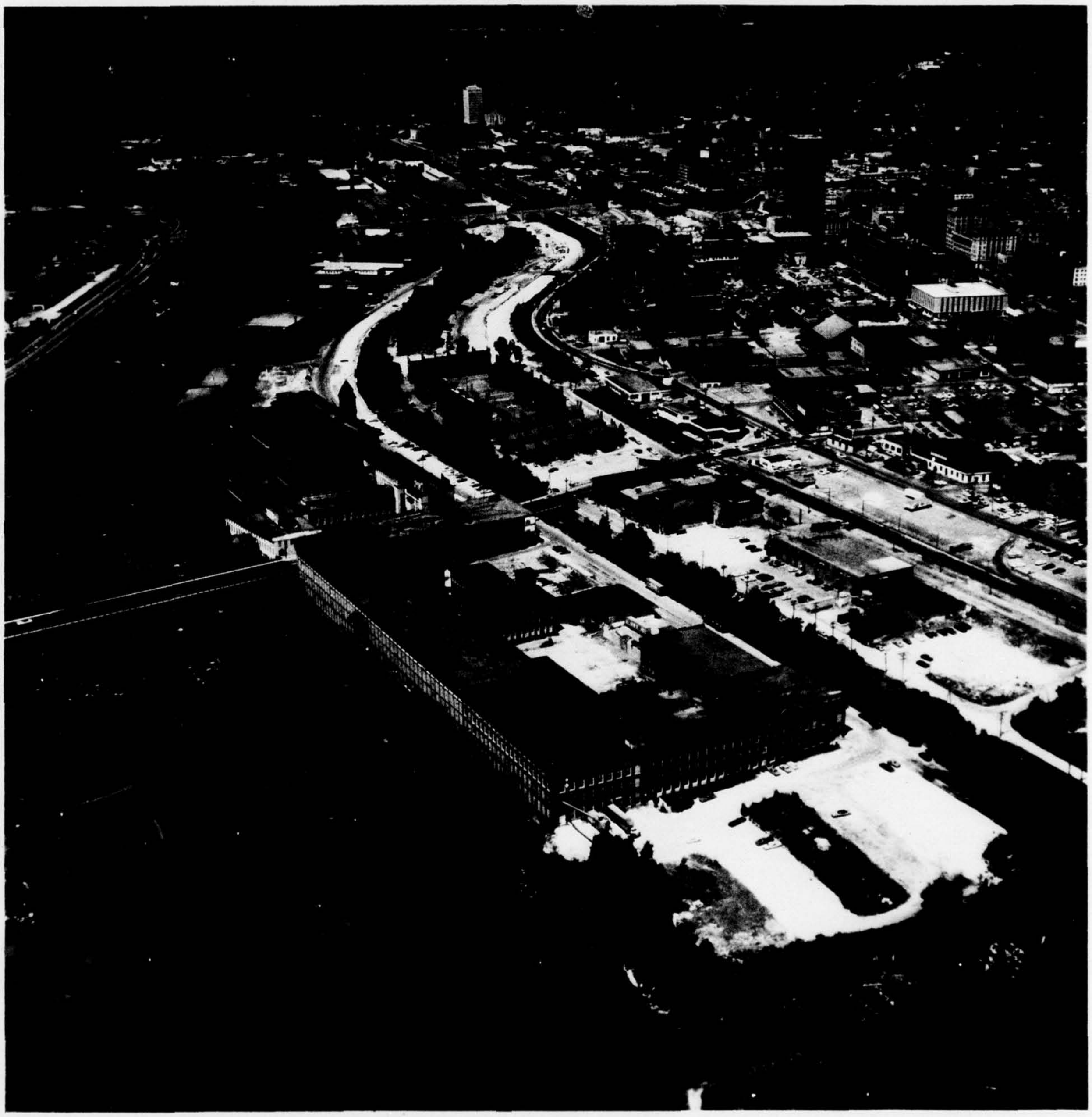
Notes:
1. Figures are in Millions of Dollars
2. Costs of schemes for reuse of renovated water are not included above
3. ENR = 1500
4. In addition to the large tunnel and pipe lines described in "Area Systems," the conveyance costs also include wastewater collection from the satellite communities in each of the six areas.

MERRIMACK WASTEWATER MANAGEMENT STUDY
ESTIMATED ANNUAL OPERATING COSTS*

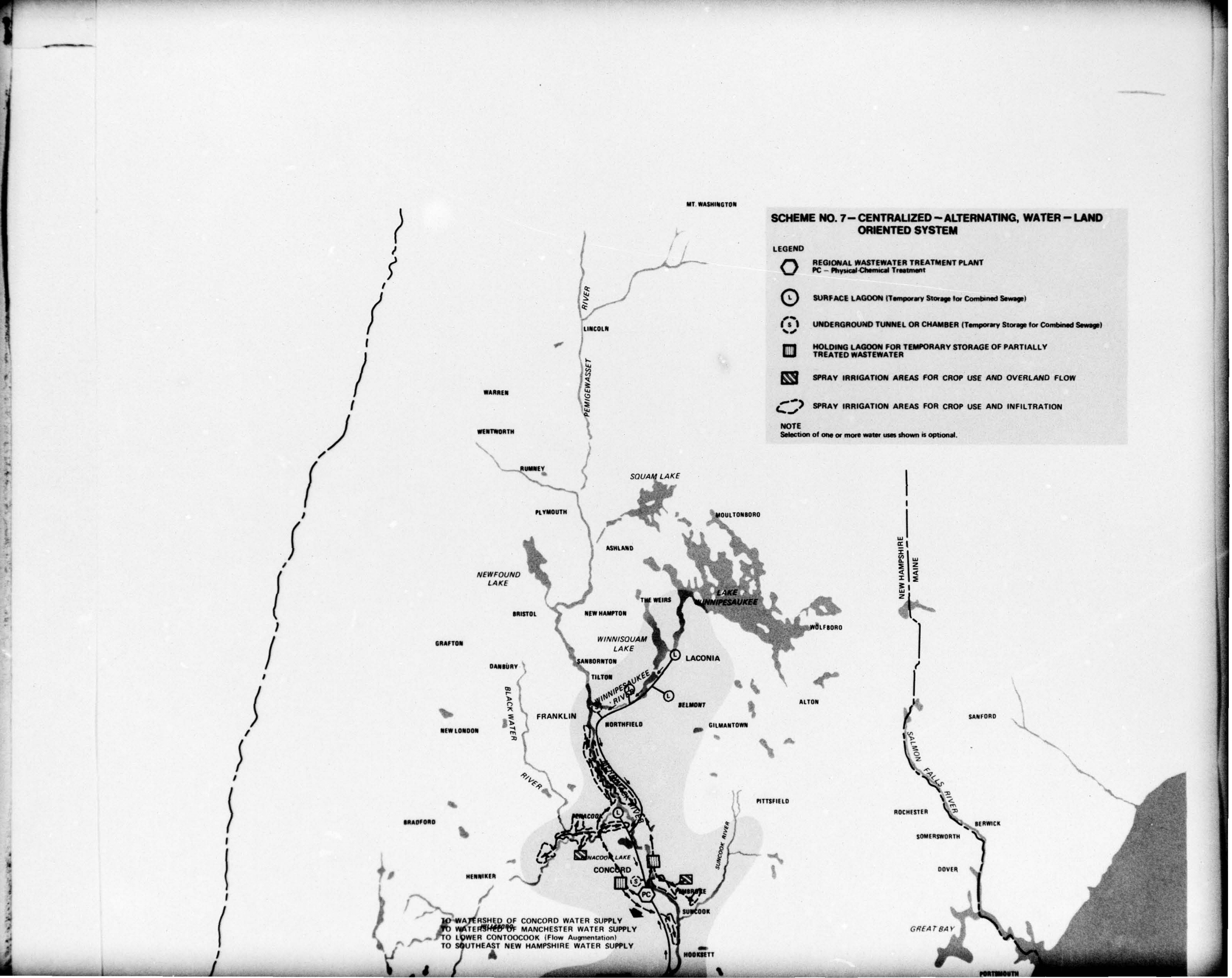
Scheme No. 6 Decentralized-Alternating, Water-Land Oriented Systems

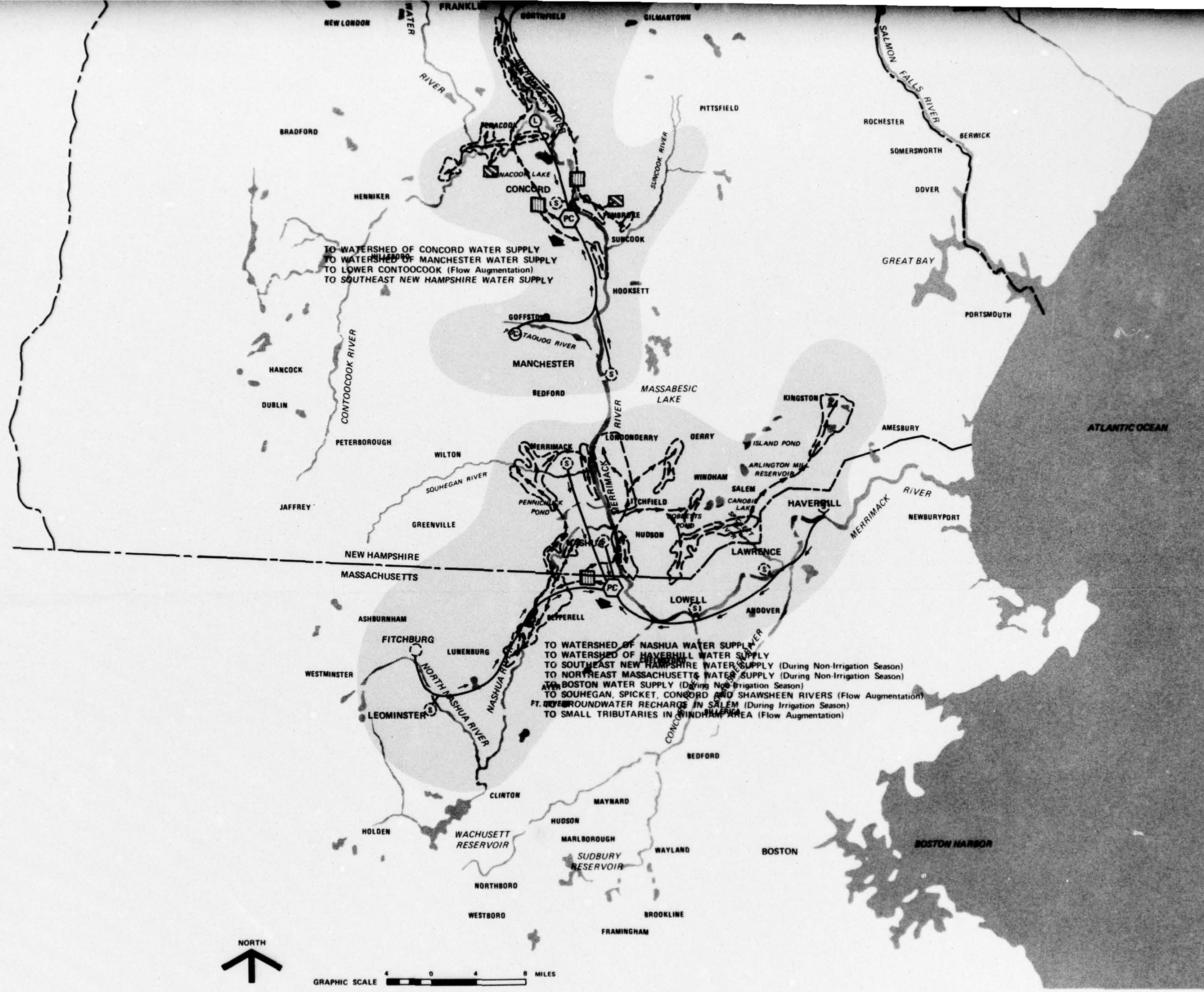
Item	L-L-H	Nashua	F-L	Manchester	Concord	Winn. River	Total
1. Annual Operating Maint. & Power Cost	$19.5	$ 7.3	$ 5.7	$ 4.5	$ 4.0	$ 2.7	$43.7
2. Annual interest & amortization on Capital Costs (5⅜%)							
a. Pipe in Place, Chambers, etc. (based on 50 yr. life)	9.4	5.2	4.2	3.4	2.9	1.3	26.4
b. Plants, Pumping, Lagoons, etc. (based on 30 yr. life)	9.5	5.1	3.8	2.1	2.5	1.3	24.3
c. Irrigation Systems (based on 20 yr. life)	—	.3	.5	.4	.3	.3	1.8
d. Estimated Annual Interest & Amortization Costs	18.9	10.6	8.5	5.9	5.7	2.9	52.5
e. Total Estimated Annual Costs	38.4	17.9	14.2	10.4	9.7	5.6	96.2
f. Say	$38.5	$18.0	$14.0	$10.5	$ 9.5	$ 5.5	$96.0

* Figures are based on the estimated construction cost and 20% contingencies
Figures are in Millions of Dollars



Merrimack River at Manchester, New Hampshire


SCHEME NO. 7 — CENTRALIZED — ALTERNATING, WATER — LAND ORIENTED SYSTEM
LEGEND
REGIONAL WASTEWATER TREATMENT PLANT
PC – Physical-Chemical Treatment
SURFACE LAGOON (Temporary Storage for Combined Sewage)
UNDERGROUND TUNNEL OR CHAMBER (Temporary Storage for Combined Sewage)
HOLDING LAGOON FOR TEMPORARY STORAGE OF PARTIALLY TREATED WASTEWATER
SPRAY IRRIGATION AREAS FOR CROP USE AND OVERLAND FLOW
SPRAY IRRIGATION AREAS FOR CROP USE AND INFILTRATION
NOTE
Selection of one or more water uses shown is optional.
MT. WASHINGTON
LINCOLN
PEMIGEWASSET RIVER
WARREN
WENTWORTH
RUMNEY
PLYMOUTH
SQUAM LAKE
MOULTONBORO
ASHLAND
NEWFOUND LAKE
BRISTOL
NEW HAMPTON
THE WEIRS
LAKE WINNIPESAUKEE
WOLFBORO
NEW HAMPSHIRE
MAINE
GRAFTON
WINNISQUAM LAKE
LACONIA
SANBORNTON
DANBURY
TILTON
WINNIPESAUKEE RIVER
BELMONT
ALTON
BLACK WATER RIVER
FRANKLIN
NORTHFIELD
GILMANTOWN
SANFORD
NEW LONDON
SALMON FALLS RIVER
PITTSFIELD
BRADFORD
ROCHESTER
BERWICK
SUNCOOK RIVER
SOMERSWORTH
CONCORD
HENNIKER
DOVER
PC
SUNCOOK
GREAT BAY
TO WATERSHED OF CONCORD WATER SUPPLY
TO WATERSHED OF MANCHESTER WATER SUPPLY
TO LOWER CONTOOCOOK (Flow Augmentation)
TO SOUTHEAST NEW HAMPSHIRE WATER SUPPLY
HOOKSETT
PORTSMOUTH


TO WATERSHED OF CONCORD WATER SUPPLY
TO WATERSHED OF MANCHESTER WATER SUPPLY
TO LOWER CONTOOCOOK (Flow Augmentation)
TO SOUTHEAST NEW HAMPSHIRE WATER SUPPLY
TO WATERSHED OF NASHUA WATER SUPPLY
TO WATERSHED OF HAVERHILL WATER SUPPLY
TO SOUTHEAST NEW HAMPSHIRE WATER SUPPLY (During Non-Irrigation Season)
TO NORTHEAST MASSACHUSETTS WATER SUPPLY (During Non-Irrigation Season)
TO BOSTON WATER SUPPLY (During Non-Irrigation Season)
TO SOUHEGAN, SPICKET, CONCORD AND SHAWSHEEN RIVERS (Flow Augmentation)
TO GROUNDWATER RECHARGE IN SALEM (During Irrigation Season)
TO SMALL TRIBUTARIES IN WINDHAM AREA (Flow Augmentation)
NEW HAMPSHIRE
MASSACHUSETTS
ATLANTIC OCEAN
BOSTON HARBOR
GREAT BAY
SALMON FALLS RIVER
CONTOOCOOK RIVER
SUNCOOK RIVER
MERRIMACK RIVER
SOUHEGAN RIVER
NASHUA RIVER
NORTH NASHUA RIVER
MASSABESIC LAKE
ISLAND POND
ARLINGTON MILL RESERVOIR
CANOBIE LAKE
PENNICHUCK POND
WACHUSETT RESERVOIR
SUDBURY RESERVOIR
FRANKLIN
NEW LONDON
NORTHFIELD
GILMANTOWN
PITTSFIELD
ROCHESTER
BERWICK
SOMERSWORTH
DOVER
PORTSMOUTH
BRADFORD
HENNIKER
CONCORD
SUNCOOK
HOOKSETT
GOFFSTOWN
MANCHESTER
BEDFORD
HANCOCK
DUBLIN
PETERBOROUGH
WILTON
JAFFREY
GREENVILLE
MERRIMACK
LONDONDERRY
DERRY
KINGSTON
AMESBURY
WINDHAM
SALEM
LITCHFIELD
HUDSON
HAVERHILL
NEWBURYPORT
LAWRENCE
LOWELL
ANDOVER
PEPPERELL
ASHBURNHAM
FITCHBURG
LUNENBURG
WESTMINSTER
LEOMINSTER
CLINTON
HOLDEN
MAYNARD
MARLBOROUGH
WAYLAND
BOSTON
NORTHBORO
WESTBORO
BROOKLINE
FRAMINGHAM
NORTH
GRAPHIC SCALE
4 0 4 8 MILES

SCHEME NO. 7: DECENTRALIZED, ALTERNATING WATER-LAND ORIENTED SYSTEM

Selection Criteria:

- Utilizes mixed technology for all areas; land requirements met totally within the Basin
- Maximizes development opportunities among urban and rural areas via wastewater transmission routes
- Maximizes economy of scale in the water oriented portion of the system with use of wastewater nutrients on the land
- Maximizes opportunities for regional cooperation

Design Criteria:

- Designed for municipal, industrial, and stormwater volume projected for 1990 (including a 2.6" rainfall in 6 hours).

Scheme Components:

Advanced

Two regional physical-chemical wastewater treatment plants with sludge incinerators

Approximately 2,400 acres of spray irrigation/overland flow with recapture system for renovated water

Approximately 36,050 acres of spray irrigation/infiltration with a recapture system for renovated water

Ten subsurface storage chambers and five surface lagoons for temporary storage of stormwater and combined sewer overflows.

Three surface lagoons for temporary storage of partially treated wastewater — 1,054 acres

Approximately 184 miles of underground sewage transmission pipes and tunnels

Approximately 115 miles of effluent distribution pipes to irrigation areas

Sludge produced by advanced treatment facilities will be incinerated on site.

Brines will be evaporated, stored, and periodically disposed of at sea.

Area Systems - 2

Northern Service Region
(Manchester, Concord, Winnipesaukee)

One regional at Concord, New Hampshire — 117 MGD capacity

Two one near the junction of the Suncook and the Merrimack and one south of Contoocook River — 2,400 acres.

along Merrimack, Contoocook and Suncook River — 10,350 acres.

Five , one each at Laconia, Belmont, Tilton and Penacook and Goffstown — 144 MG, 10 MG, 125 MG, 50 MG, and 37 MG capacity

Three one each at Franklin, Concord, and Manchester — 47 MG, 209 MG, 227 MG capacity.

Two for temporary storage of partially treated wastewater — 330 acres.

Transmission system connecting all areas to at Concord — 67 miles.

40 miles of distribution pipes carrying effluent to irrigation sites.

Southern Service Region
(Nashua, Fitchburg-Leominster, Lowell-Lawrence-Haverhill)

One regional at Lowell, Massachusetts — 259 MGD capacity.

in the Pennichuck and Souhegan Valleys, in the Nashua River Valley, along the Merrimack River, north of Lowell and in the Little and Exeter River Valley north of Haverhill to Kingston, N. H. — 25,700 acres.

Seven Ⓢ, one each at Fitchburg, Leominster, Lowell, Lawrence, Haverhill, Nashua and Merrimack — 278 MG, 82 MG, 277 MG, 307 MG, 149 MG, 216 MG and 94 MG capacity.

One Ⅲ for temporary storage of partially treated wastewater — 724 acres.

Transmission system connecting all areas to ⓅⒸ at Lowell — 117 miles.

Distribution pipes carrying effluent to the irrigation sites — 75 miles.

Discussion

In the counterpart of Scheme 3 which employed only water oriented technologies, Scheme 7 proposes to continue to service the same two large areas with a modification that land renovation techniques now be used in parallel with water oriented technologies.

This configuration of water and land oriented processes is somewhat unique in that two different treatment systems serve each of the areas. During the winter months wastewater would receive the full range of physical-chemical treatment prior to discharge.

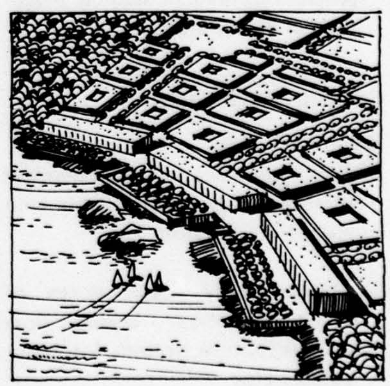
During those seasons when land renovation techniques are possible, i.e. the period from mid-April or early May through late September or mid-October, partial renovation using coagulation-sedimentation and chlorination would be accomplished prior to final renovation by spray irrigation on land.

The length of the irrigation season could be adjusted each year depending upon climatic conditions. If heavy rains occurred some year throughout April and May, then the entire physical-chemical advanced wastewater treatment plant could operate until June. If a hurricane with torrential rains hit the Merrimack River Basin in early September and above average rainfall continued throughout the rest of the month, the entire plant could begin operating before it normally would.

Sludge would be incinerated and the residue incorporated in landfill. Brine will be evaporated, stored, and periodically disposed of at sea.

This scheme and scheme 3, both with large regional physical-chemical plants south of Concord and west of Lowell, are the most complex from the institutional and political standpoint. While such complexity might first appear to be a disadvantage, it also presents some advantages in that it is this same complexity which now requires co-operation and coordination between governmental units. Interstate and inter-regional interests concerning adequate water supply and water quality control might best be served by just such a wide-scale plan.

This scheme calls for a dual system and therefore presents a disadvantage in terms of additional cost.



Waterfront Wastewater Plant

Flow Augmentation Outfall

However, this must be weighed against the considerable advantage such a flexible back up system provides. Both physical-chemical plants and land for irrigation are necessary. However, land requirements are only about 40 percent of requirements for the all land disposal scheme. Further, operating costs for carbon adsorption units are high, but this cost would be saved during the irrigation season. Maintenance of equipment in the plants would be done during the summer.

A further disadvantage with this scheme (and scheme 3) may be the cost of pumping untreated wastewater greater distances to the treatment facilities than is required under less centralized schemes. However, such transmission lines would also serve for temporary storage of high stormflows, thus reducing the need and cost of special, underground storage facilities.

If this scheme is implemented, secondary treatment plants in existence will be evaluated to determine whether they should be integrated into the system or abandoned and their costs added to the overall cost of the scheme.

Some specific uses for the reclaimed water are listed on page 101. The costs associated with these uses, however, are not included in the estimate.

Some of the impacts associated with this scheme are listed here:

- *Creation of new suitable habitat along transmission pipes may increase the quantity of deer and other game.*
- *Within the irrigation area there will be an increase in the number of insects, especially mosquitoes.*
- *A major disturbance will occur in the terrestrial environment at the given treatment plant sites.*
- *Lagoons will require extensive land manipulation and disruption of natural conditions.*
- *Diversion of flow from the Nashua River will have an unfavorable impact on this stream during low flow periods.*
- *The addition of nitrogen and moisture will accelerate bacterial action with increased reduction of forest duff (surface organic litter).*
- *Pitch pine will develop a more shallow root system under irrigation and be subject to greater degrees of windthrow damage.*
- *Transmission pipes to regional facilities will considerably disrupt the landscape.*
- *Land disposal sites will be looked at with pride or become a thing to hide depending on planning, design, and operation.*

Transmission Line Right-of-way Summer

Transmission Line Right-of-way Winter

- *The preservation of open space along transmission lines may significantly increase the visual diversity of the landscape.*

- *There will be a major disruption of the scenery at plant sites during construction.*

- *Cooperation between various communities and/or states will result in more effective decision processes.*

- *Imaginative design of facilities can develop a large potential for multiple use.*

- *With proper management more valuable tree species could be encouraged within the land disposal sites.*

- *Employment during construction of the wastewater facilities will increase.*

- *The utilization of wastewater as a valuable resource will be realized.*

- *Considerable acreage will remain in a semi-natural state.*

BEYOND THE YEAR 1990

The seven schemes considered here are sufficiently flexible to be expanded using existing technology. However beyond 1990, technological change should be of sufficient magnitude to affect the water management problems in the Merrimack Basin.

Water oriented disposal techniques will probably be the most likely way of system expansion with the use of present technology and with the expected continuing growth in water demand and wastewater production. These techniques will probably include physical-chemical advanced wastewater treatment plants.

In Schemes 1, 2 and 3, expansion in the regional facilities is one possibility. This would entail treating raw sewage as well as some secondary plant effluent that would constitute a diminishing portion as time progressed.

Scheme 3 could include the development of satellite plants that would take on the load of some portion of either the Northern or Southern Service Region. The emerging technology of water additives to increase flow rates in pipes could be used to move larger amounts of effluent through the same system.

Scheme 4 would become a combination scheme with the addition of an advanced treatment plant.

Scheme 5, 6, and 7 could be enlarged with both treatment plants and land disposal areas.

Emerging technology hopefully will bring better in-plant reuse of industrial waters and with it smaller quantities of effluent even if they convey an increased waste load. Greater waste loads can be accommodated in physical-chemical advanced treatment plants far easier than greater water volumes.

The development of the infiltration or flooding basin technique of land disposal might even reduce the land requirements while increasing wastewater handling capability. This technique, based on high rate infiltration and alternating aerobic and anaerobic soil conditions is now under study. A research institute in the Merrimack Basin recently submitted a research proposal for field evaluation.

Finally, if technology should make some of our works totally obsolete in the distant future, the open land will keep its value for the people in the Merrimack. The open land beyond the year 2000 is likely to be more valuable for open areas and recreation than for any other use.

POTENTIAL USES FOR RECLAIMED WATER — SCHEME NO. 7

NORTHERN SERVICE REGION

WINNIPESAUKEE-CONCORD-MANCHESTER 93 MGD (74 MGD in irrigation season)

- *Return to watershed of Penacook Lake for Concord's water supply.*
- *Return to watershed of Massabesic Lake for Manchester's water supply.*
- *Flow augmentation in the lower Contoocook River.*
- *To southeastern New Hampshire water supply.*

SOUTHERN SERVICE REGION:

NASHUA-LEOMINSTER-FITCHBURG-LOWELL-LAWRENCE-HAVERHILL 216 MGD (173 MGD in irrigation season).

- *Flow augmentation in many small streams in the Windham area of New Hampshire.*
- *Recharge shallow groundwater aquifiers in Salem area during irrigation season.*
- *Return to watershed of reservoir system of Haverhill.*
- *Return to watershed of Pennichuck Brook for supplementation of Nashua's water supply.*
- *Flow augmentation in tributaries of Merrimack River such as the Concord, the Shawsheen, the Souhegan, and the Spicket Rivers.*
- *To southeastern New Hampshire water supply during non-irrigation season.*
- *To Boston for water supply during non-irrigation season — exchange for low flow releases into the Nashua River from Wachusett Reservoir.*
- *To northeastern Massachusetts water supply during non-irrigation season.*

MERRIMACK WASTEWATER MANAGEMENT STUDY
ESTIMATED COST BREAKDOWN (CAPITAL EXPENDITURES)

Scheme No. 7 Centralized-Alternative, Water-Land Oriented Systems

Item	L-L-H & F-L & Nashua	Manchester & Concord & Winn. River	Total
Construction			
Conveyance System	$83.0	$ 37.1	$120.0
Stormwater Storage	234.6	89.5	324.1
Basic Treatment	—	—	—
Advanced Treatment	58.6	31.0	89.6
Holding Lagoons	8.8	4.0	12.8
Irrigation System	18.0	7.2	25.2
Overland Flow	—	1.2	1.2
Sub-Totals	403.0	170.0	573.0
Constr. Contingencies (20%)	80.6	34.0	114.6
Sub-Totals	483.6	204.0	687.6
Superv. & Admin.* (8%)	38.6	16.0	54.6
Sub-Totals	522.2	220.0	742.2
Engineering** (10%)	48.3	20.4	68.8
Sub-Totals	570.5	240.4	811.0
Land Aquisition	21.3	10.9	32.2
Total Est., Costs	591.8	251.3	843.2
Say	$592.0	$251.0	$843.0

* 8% of Construction and Contingencies
** 10% of Construction and Contingencies

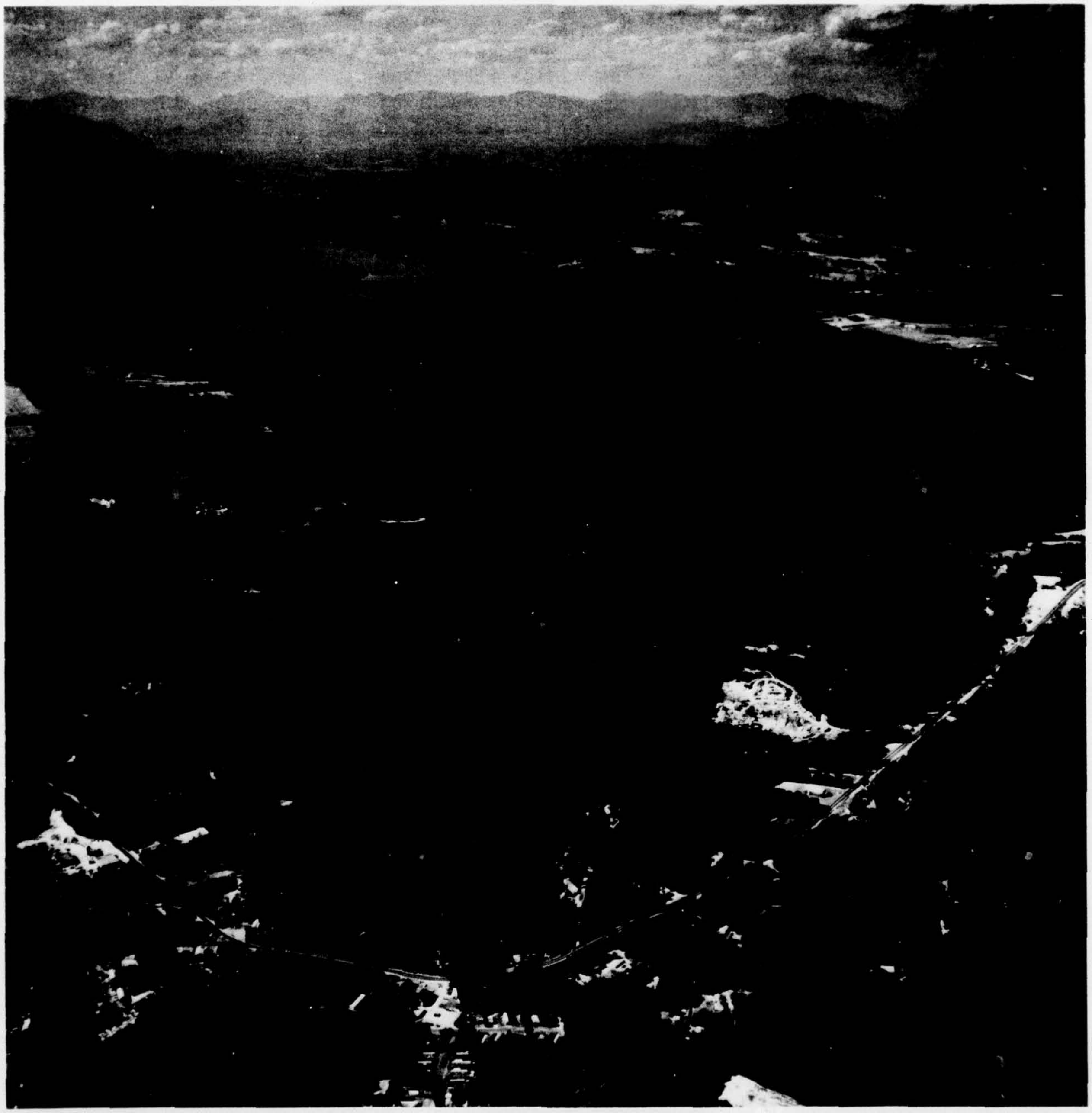
Notes: 1. Figures are in Millions of Dollars
2. Costs of schemes for reuse of renovated water are not included above
3. ENR = 1500
4. In addition to the large tunnel and pipe lines described in "Area Systems," the conveyance costs also include wastewater collection from the satellite communities in each of the six areas.

MERRIMACK WASTEWATER MANAGEMENT STUDY
ESTIMATED ANNUAL OPERATING COSTS*

Scheme No. 7 Centralized-Alternating, Water-Land Oriented Systems

Item	L-L-H & F-L & Nashua	Manchester & Concord & Winn. River	Total
1. Annual Operating, Maint. & Power Cost	$25.7	$10.5	$36.2
2. Annual Interest and Amortization on Capital Costs (5⅜%)			
a. Pipe in Place, Tunnels, Chambers, etc. (based on 50 yr. life)	21.0	7.5	28.5
b. Plants, Pump Houses, Lagoons, etc. (based on 30 yr. life)	7.0	3.7	10.7
c. Irrigation Systems (based on 20 yr. life)	1.8	.9	2.7
d. Estimated Annual Interest & Amortization Costs	29.8	12.1	41.9
e. Total Estimated Average Annual Costs	55.5	22.6	78.1
Say	$55.5	$22.5	$78.0

* Figures are based on the estimated construction cost and 20% contingencies
Figures are in Millions of Dollars



Lake Winnisquam

EVALUATION

This section deals with how well the seven illustrative schemes developed in this report meet the specific objectives of the feasibility study and the water resources planning objectives established by the Water Resources Council.

The specific objectives of the feasibility study are, 1) the ultimate achievement of maximum feasible water purity and 2) to use wastewater, a resource too valuable to discard, to its fullest and best purpose by making it and its constituent pollutants available for re-use. All seven schemes meet both specific objectives of the feasibility study by producing maximum feasible water purity in major waste discharges reaching the Merrimack and allowing a wide range of water re-use.

The U.S. Water Resources Council has established four separate objectives for water resources planning. These are broad classes of social values that a water program may be able to effect. These include: Environmental Quality, Social Well-Being, Regional Development, and National Economic Development.

The seven illustrative wastewater management schemes presented in this report are evaluated here in three ways. First, they are compared among each other by monetary cost. Second come their potential impacts on the present and projected characteristics of the Merrimack Basin. On the evaluation of impacts, special attention is given to the new opportunities for improvement and development offered by each strategy. Finally, schemes are assessed for the problems present when implemented.

To make comparisons among schemes valid and useful, a common yardstick has been applied. That measure is the set of four objectives or accounts developed for water resource planning. Applied specifically to impacts and by implication to the other categories, these broad classes of social values indicate, at least in a general way, where the benefits and costs of a given strategy tend to cluster. For the purposes of this discussion "benefits" are taken to include those expenditures, impacts, and opportunities which move toward a Council objective and, conversely, "costs" indicate a retreat.

Monetary Costs

Capital and operating expenditures are costs chargeable against all four objectives. As such, they can be measured in terms of opportunities foregone in not funding other projects which also address these social values. But cost can also produce impressive benefits. For example,

MERRIMACK WASTEWATER MANAGEMENT STUDY
COST SUMMARY (ALL COSTS ROUNDED TO MILLION DOLLARS)

Scheme	EPA	1	2	3	4	5	6	7
Construction								
Conveyance System		$ 30	$ 39	$ 57	$178	$ 72	$ 65	$120
Stormwater Storage		318	325	323	330	323	324	324
Basic Treatment	$235	139	134	—	—	100	138	—
Advanced Treatment		128	118	89	—	79	128	90
Treatment Lagoons		—	—	—	165	59	16	13
Irrigation Systems		—	—	—	54	19	16	28
Sub-Totals		615	616	469	727	652	687	573
Const. Contingencies (20%)		124	124	94	146	132	138	115
Sub-Totals		739	740	563	873	784	825	688
Supervision & Admin.*		60	60	45	72	64	66	54
Sub-Totals		799	800	608	945	848	891	742
Engineering**		74	74	56	88	78	83	69
Sub-Total		873	874	664	1033	926	974	811
Land Acquisition		3	3	4	75	32	22	32
Total Estimated Costs	235	876	877	668	1108	958	996	843
Annual Operation, Maint. & Power Cost	13	50	49	42	34	45	44	36
Estimated Annual Interest & Amortization & Major Replacements	16	46	46	32	54	49	52	42
Total Estimated Annual Cost	$ 29	$ 96.0	$ 95.0	$ 74.0	$ 88.0	$ 94	$ 96	$ 78

* 8% of Construction Costs and Contingencies
** 10% of Construction Costs and Cintigencies
Based on 1990 Design and ENR = 1500

any funds raised elsewhere and spent in the basin represents "found money" which brings with it expanded regional development and its attendant benefits to employment, housing, recreation, etc.

Total estimated capital costs and average annual costs are summarized for all Corps schemes and for the EPA-State implementation program in a cost table. Note that average annual operating costs for schemes 1 through 7 have a far smaller range than their several capital costs. This happens because the most capital intensive alternative, scheme 4, also has the lowest operating costs. Conversely, in scheme 3, capital costs are relatively low, while operating expenditures are high. Moreover, note that treatment plants depreciate to a value approaching zero at the end of their useful life, while land as used in schemes 4 through 7 retains its intrinsic value.

When comparing the investment required to implement each scheme, the cost of the EPA-State program must be kept in mind. Schemes 1, 2, and 6 utilize the existing implementation schedule fully, and scheme 5 incorporates it in part. Total costs, therefore, include all or a portion of the $235 million slated for the construction of basic water treatment facilities; the difference between total estimated costs and EPA-State program costs represent expenditures for the substantial increment in water quality that advanced treatment techniques can deliver. In schemes 3, 4, and 7, which do not contemplate using existing EPA-State plans, the investment costs associated with these plans, less depreciation, are a liability which must be added to the expense of Corps strategies. Further, in all cases total figures include more than $400 million for stormwater capture and treatment systems, $324 million for storage, and the remainder for extra plant capacity. Because of the preliminary nature of all Corps alternative costing, totals represent approximations rather than final dollar amounts and a ranking of schemes by cost may be deceptive.

Impacts and Opportunities

Relative to the four social objectives set out above, the value of an impact depends upon how the solution that produces it affects the physical and human resources of the region. Generally, an impact can be characterized by direction, magnitude — if quantification is appropriate — and by duration. At the feasibility study level, the effort has been to collect a wide range of changes that any given solution may have in the basin, New England, or even the Nation, and organize them for more detailed examination in later study phases.

On the impact table evaluations are arranged by scheme according to the Water Resources Council objectives; benefits and costs attendant on each solution are easily compared. Under each objective, impacts are broken into three sections. First, uniform impacts are those which are associated with all solutions, that is, they all have the same effect on the needs and resources of the Basin, producing like benefits and costs. Second, other impacts which relate only to the EPA-State implementation program or only to the seven Corps schemes are described. Last are the many diverse impacts which are specific to individual schemes.

A final word about *opportunities*, a special class of impacts which become available when a solution is implemented. Not included in the cost figures shown earlier, these are possible returns on the clean water investment of the people of the Basin. They are usually associated with new land and water uses not available before and ecologic improvements which impinge directly on the quality of human life. Superclean (advanced treatment) effluent, for example, can be returned directly to a lake or stream to improve appearance and increase the desirability of shoreline land. Or it may go into a public water supply in a town experiencing water shortages; where there is no local need, clean water can become a valuable commodity for export to less fortu-

MERRIMACK WASTEWATER MANAGEMENT STUDY —

OBJECTIVES		Uniform for all Eight Solutions	EPA-State Implementation Program	Common to all Seven Schemes	Scheme 1	Sche
Environmental Quality	BENEFITS:	Considerable increase in benthic organisms, fishery resources, birds, and waterfowl; Establishment of additional species of plants and animals.	Favorable effect upon species diversity and ecosystem stability; Significant improvement in clarity, odor and taste of Merrimack River Water.	Very favorable effect upon specie diversity and ecosystem stability in the rivers; great improvement in clarity, color, odor, and taste of Merrimack water; Reduced potential of algae problem.		Along tra sion pipe landscap sity may and wildli habitat m improve.
	COSTS:	Some degradation in terrestrial ecology near plant sites.	Potential of Algae problem.		Some temporary disturbance of scenery and permanent disturbance of terrestrial ecology.	Same as 1; modera ruption of by transm pipe route
Social Well-Being	BENEFITS:	Increased availability of cleaner water; reduction in bacterial pollution with general public health benefits	Considerable enhancement of potential for water recreation; Improvement of Merrimack as a water source; Provision of a better and more attractive place in which to live.	Great enhancement of potential for water recreation; Further improvement of the Merrimack as a water source; Provision of better, more attractive place to live which will raise community pride and attract people.	Provide for limited cooperation between communities and states; development potential for multiple use of wastewater facilities.	Provide f cooperati tween co nities and develops for multip of wastew facilities.
	COSTS:	Possible increase in demand for services from additional population.				
Regional and National Economic Development	BENEFITS:	Increase of commercial enterprises catering to recreationists.	Industry will benefit; Land values and development will be affected and the tax base of river towns will rise; Long run employment could increase; finfish industry will be significantly improved.	Industry will benefit markedly; Land values will be significantly affected; Land development and land planning will be greatly affected; The tax base will rise; Long and short term employment will increase; Local flooding will be greatly reduced; Finfish industries will be greatly improved. Sport fishing industry will grow rapidly.	Some nutrients will be provided by sludge.	Same as Scheme 1
	COSTS:		Local taxes may rise.	Local taxes may rise.		

2

ER MANAGEMENT STUDY — EVALUATION OF IMPACTS

	SCHEMES PRESENTED IN THIS REPORT						
	Scheme 1	**Scheme 2**	**Scheme 3**	**Scheme 4**	**Scheme 5**	**Scheme 6**	**Scheme 7**
t y ility ty, e l		Along transmission pipe routes landscape diversity may increase and wildlife habitat may improve.	Along many miles of transmission pipe routes landscape diversity may increase and wildlife habitat may improve.	Along very many miles of transmission pipe routes landscape diversity may increase and wildlife habitat may improve; considerable acreage remains semi-natural.	Same as Scheme 4 except moderate acreage remains semi-natural.	Same as Scheme 5	Same as Scheme 5
	Some temporary disturbance of scenery and permanent disturbaice of terrestrial ecology.	Same as Scheme 1; moderate disruption of scenery by transmission pipe routes.	Same as Scheme 1 over greater area; significant disruption of scenery by transmission pipe route; considerable reduction of flow in Nashua River.	Same as Scheme 3; extensive disruption of natural conditions by lagoons and land disposal areas; possible damage to pitch pines and to forest duff; possibility of spreading pathogens through *waterfowl on* lagoons.	Same as Scheme 4, except no flow loss in Nashua River.	Same as Scheme 3, except no flow loss in Nashua River; moderate disruption of natural condition in land-disposal areas; possible damage to pitch pine and forest duff.	Same as Scheme 3; significant disruption of natural conditions in land disposal areas.
of m- ir- ve vill de	Provide for limited cooperation between communities and states; development potential for multiple use of wastewater facilities.	Provide for some cooperation between communities and states; develops potential for multiple use of wastewater facilities.	Provide for considerable cooperation between communities and states; develop large potential for multiple use of wastewater facilities.	Same as Scheme 3	Provide for some cooperation between communities and states; develop large potential for multiple use of wastewater facilities.	Same as Scheme 5	Same as Scheme 3
				Land disposal areas may be unsightly and may increase the number of insects.	Same as Scheme 4	Same as Scheme 4	Same as Scheme 4
ies l- an- se e - e y	Some nutrients will be provided by sludge.	Same as Scheme 1		Large scale use of waste water in crop production; Improvement in quality and quantity of timber; nutrients will be provided by sludge.	Same as Scheme 4	Same as Scheme 4	Large scale use of wastewater in crop production; improvement in quantity of timber.
.							

nate areas in return for some attractive considerations concurred in by the public. Transmission lines themselves offer myriad opportunities for cohesive regional planning; open spaces can be protected by channeling industrial and residential development along predetermined corridors which complement the landscape and the life styles of Basin residents. Likewise, underground piping systems can supply clean water to entirely new recreational areas which can relieve the growing pressure on existing swimming, camping, and boating facilities and bring leisure-time activities closer to home.

Likewise, other species can benefit from water renovation. Sport fish unable to survive in polluted streams will become viable in a new Merrimack. Terrestrial animals can profit from the kinds of forest management proposed under some schemes. In all cases, man is the beneficiary of an improved environment.

Implementation Problems

Implementation is an integral part of any scheme. Without the ability to carry a plan to fruition, the most technically, economically or ecologically advantageous scheme is useless. There are significant differences between the seven schemes presented in this report as they relate to their implementation. The EPA-State implementation plan is now a vigorous on-going program with some treatment plants built, some under construction, some designed, and some still in the preliminary planning stage. Any program that builds on the momentum generated by this effort is likely to succeed faster. Conversely, an abrupt reorientation of the State effort is likely to cause delays and institutional complications.

Another consideration bearing on implementation is the complexity of the institutional arrangements that are needed to accomplish the task. In general the fewer political entities that are involved in a plan or in a major component of a plan, the lesser the institutional complexity.

Schemes 1, 2, and 6 incorporate the entire definitely developed portions of the EPA-State implementation program. Scheme 5 incorporates a major part. Scheme 4 can be easily adapted to incorporate any or all of the secondary plants built, in lieu of treatment lagoons. Only schemes 3 and 7 would require some redirection of the State effort.

In the area of complexity, scheme 1 is likely to have the least institutional problems, closely followed by schemes 2, 5, and 6. Schemes 3, 4, and 7 are likely to be most complex institutionally as arrangements to implement them must simultaneously cover many communities and two or more states.

There are no mathematical formulae which permit one to weigh and add up the array of criteria for measuring implementation difficulty relative to on-going programs and complexity of institutional arrangements. Detailed studies will be needed to evaluate correctly the relative chances of the more implementable schemes. Following this preliminary evaluation, however, the conclusion can be drawn that schemes 3 and 7 are likely to be the most difficult ones to implement.

SUMMARY AND CONCLUSION

The presently polluted state of the Merrimack River presents a problem not only directly to the river and its plants and animals, but to people. This problem is not limited to those that live along the river banks. It is a problem common to the State of New Hampshire, the Commonwealth of Massachusetts, and the United States, since a significant portion of the United States population resides within a few hours of travel time from this Basin. The economic potential of a clean river is significant; however, the Merrimack is an interstate river which has a pollution problem that exists now.

The EPA-State implementation program that will develop and upgrade municipal sewage treatment in the Basin provides one answer to some of the problems of the Merrimack River. The construction of the sewage treatment plants in this program will, in the judgment of those planning them, upgrade the water quality of the Merrimack to the presently accepted Federal-State water quality standards. While this program will markedly improve or correct many water quality problems related to oxygen demand, discharge of suspended solids and bacterial contamination, other problems will persist.

Resources of all kinds can no longer be thought of as unlimited. A more complete view of resources management, and specifically water management is needed. This view should encompass both extensive and intensive wastewater management which produces effluent of maximum feasible purity. Water supplies for the areas in and especially near the Basin, are reaching the limit of their development. Thus, reuse of treated waters will become more frequent. The achievement of maximum feasible purity would free the river not only from most of its pollution burden, but would make its waters available at any point along its course for all uses, contemplated or only hoped for.

The seven alternative schemes presented here represent such a different view. They should be viewed for what they are, possibilities that present-day technologies offer. The seven alternatives show seven ways in which the job of complete wastewater management, the treatment of all point sources in the urban study area, can be approached. More could be developed, but these seven illustrate the range of options. They are the first imputs into the decision-making process.

This leads to the next step; informed decisions made by the people of the Basin and by all levels of government. These decisions must be made based on thoroughly developed facts which can only come from a more detailed study, a study of "Survey" scope.

This "Survey" scope must consider among many items some specific issues which have been raised in this feasibility study itself, and in the preliminary review of its draft. For example, Survey scope should:

- *Define the goal of waste management in view of total resource management and economic realities.*
- *Explore additional alternatives which treat stormwater to a lower degree.*
- *Examine issue of intra- and interstate transfer of water from wastewater renovation plants from technical, ecological, social, economic, political, and legal points of view.*
- *Consider the relationship between schemes and the regional development goals associated with land-use planning.*
- *Consider the special problems and opportunities — social, ecological, institutional and economic — that may develop with the use of large tracts of land for water renovation.*
- *Consider extension of the service areas discussed in the feasibility report to include additional areas around Lake Winnipesaukee and on the Estuary.*
- *Consider time-phasing of projects and the possibility and desirability of implementing separate plans for some service areas as demonstration projects.*
- *Develop and implement techniques to stimulate participation from the public and from the concerned levels of government; all actors must be provided with ample opportunity to express their opinions and appropriately influence the planning process.*

Activated Sludge, a secondary treatment process where primary effluent is mixed with air and recirculated sludge that is heavily laden with bacteria.

Adsorption, a process of passing pretreated wastewater through a media such as carbon and having the dissolved organic matter concentrate on the media surface.

Aeration, intimate mixing of air and water by physical means to increase the dissolved oxygen levels.

Algae, chlorophyll containing aquatic plants characterized by their ability to carry out photosynthesis and associated with taste and odor problems in water.

Anadromous Fish, any species of fish, such as the Atlantic Salmon, which spend most of their life in the ocean but migrate into freshwater for spawning.

Bacteria, the simplest form of plant life capable of supporting all life processes for growth and reproduction — microscopic, one celled and colorless.

Benthic Organisms, plants or animals that live on or in the bottom materials of a lake or stream.

Biodegradable Organics, wastes contributed to domestic and industrial sewage which may be biologically oxidized.

BOD (biochemical oxygen demand), measure of wastewater pollutional strength based on the amount of oxygen required by bacteria to oxidize organic waste.

Brines, waters characterized by high dissolved solids concentrations and due to regeneration of ion exchange resins.

cfs, flow rate in cubic feet per second; 1 cfs = 0.65 million gallons per day.

Coagulation, the combining of solids, by charge neutralization, to make them settle faster.

COD (chemical oxygen demand), measure of wastewater pollutional strength based on the oxygen consumed in a chemical reaction.

Combined Sewer, carries municipal, industrial and stormwater in a common pipe.

Denitrification, conversion of nitrate nitrogen to gaseous nitrogen, a normal atmospheric constituent.

Dissolved Solids, solids that pass through filter mats and require tertiary treatment for removal.

Effluent, liquid which emerges from a treatment process.

Eutrophication, the natural aging processes in a body of water.

Filtration, removal of suspended solids from wastewater using adsorption and straining processes as the wastewater flows through media such as sand or carbon.

Floc, a settleable group of solids formed in wastewater treatment by chemical or biological processes.

Flocculation, process by which solids aggregation occurs by bridging.

Heavy Metals, mineral elements such as mercury that are toxic in low concentrations to plant and animal life.

Incineration, combustion of sludge to reduce the volume and produce a sterile ash.

Industrial Wastewater, water containing pollution resulting from manufacturing processes.

Influent, the liquid that enters a treatment process.

Ion, an electrically charged atom or group of atoms.

Ion Exchange, process of removing dissolved inorganic mineral salts from wastewater.

Lagoons, ponds in which sunlight, algae, and oxygen interact to restore water quality.

MGD, flow rate in million gallons per day; 1 MGD = 1.5 cubic feet per second.

Molecule, the smallest particle of a compound that can remain in a free state and still keep the characteristics of the compound.

Municipal Wastewater, water containing pollution resulting from domestic wastes; typically feces and laundry wastes.

Nitrification, sequential conversion of ammonia nitrogen to nitrate nitrogen.

Nutrients, substances such as nitrogen and phosphorus utilized by plants in their life processes.

Organic, having molecular composition including carbon in combination with one or more elements such as hydrogen or oxygen.

Oxidation, consuming or breaking down of organic wastes or chemicals in sewage by bacterial action or chemical oxidants.

Pathogens, disease producing organisms.

Physical-Chemical Treatment, renovation of raw wastewater without the use of biological oxidation processes.

Pollution, results when something — animal, vegetable, or mineral — reaches water, making it more difficult or dangerous to use for drinking, recreation, agriculture, industry, or wildlife.

Polymers, synthetic organic chemicals that act as coagulants to improve the removal of suspended solids.

PPM, parts per million, 1 ppm = 1 part of the substance concentrated in one million parts of water (by weight).

Primary Treatment, removes large floating objects and settleable solids which are respectively screened and settled out of solution.

Refractory Organics, stubborn dissolved organic wastes such as detergents which resist biological oxidation.

Salts, minerals that water picks up as it passes through the air, over and under the ground, and through household and industrial uses.

Sedimentation, removal of settleable solids by gravity.

Settleable Solids, suspended solids that will separate by gravity under quiescent conditions.

Sludge, solid matter that settles in sedimentation tanks.

Solids, matter that remains as residue upon evaporation and drying at slightly above the boiling point of water.

Spray Irrigation-Infiltration, spreading wastewater on sandy soils where it is renovated as it passes through the plants and soil.

Spray Irrigation-Overland Flow, spreading wastewater on sloping soils where it is renovated as it slowly flows across the surface of the soil and through the vegetative cover.

Stormwater, rainwater containing pollution such as animal feces, chemicals, and refuse from streets and agricultural fertilizers and pesticides.

Suspended Solids, undissolved solids in a water sample that will not pass through a filter mat.

Terrestrial Organisms, plants or animals which live on the land.

Tertiary Treatment, renovation of a biologically treated wastewater by using chemical and mechanical systems.

Toxic Organics, stubborn dissolved organic wastes such as pesticides and highly poisonous industrial chemicals like cyanide that resist biological oxidation.

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